ENGINE EXHAUST & THRUST REVERSE

OVERVIEW

The Exhaust System is made up of nacelle components that form a flow path directing the air from the engine core and the engine fan.

The shape of the nacelle is optimized to minimize drag and to maximize the thrust from the engine.

The Exhaust System is made up of two subsystems: Thrust Reverser, and Turbine Exhaust.

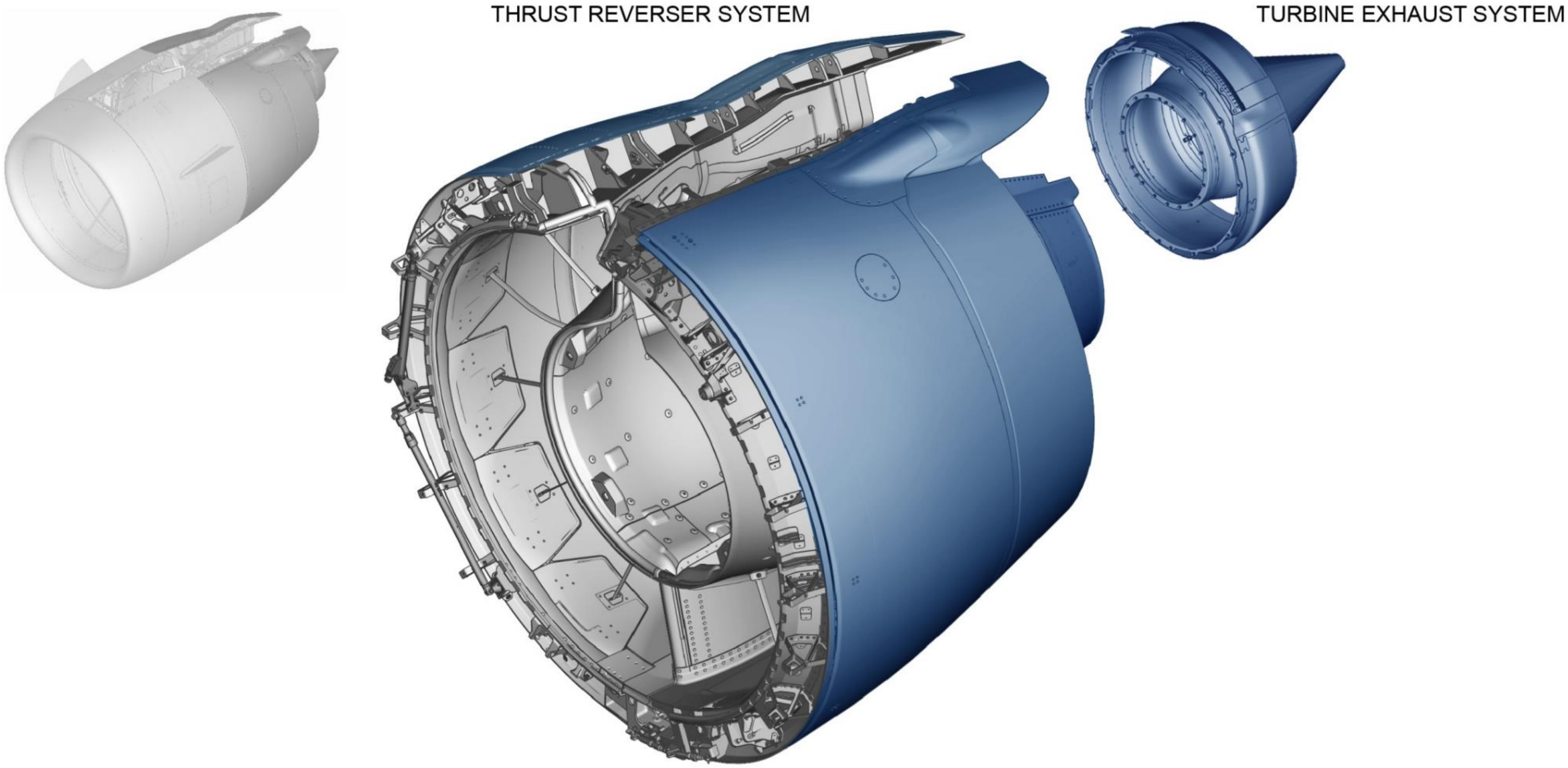
Thrust Reverser System

The Thrust Reverser System protects the engine core, forms a path for fan bypass air and deploys to slow the aircraft upon landing.

Turbine Exhaust System

The Turbine Exhaust System makes the path for the turbine gases exiting the engine core.

It gives direction to the turbine gases, which helps to increase thrust and reduce turbulence.


THRUST REVERSER SYSTEM
TURBINE EXHAUST SYSTEM

THRUST REVERSER SYSTEM

The Thrust Reverser System provides the aerodynamic braking for the aircraft on the ground.

Reverse thrust reduces the distance the aircraft needs to safely and efficiently stop during a landing or aborted take-off.

During taxi and flight the reverser provides an efficient flow path that sends air aft for maximized thrust.

Thrust reverser cowls are attached to the pylons on the left and right sides of the engine.

Some major system components are shown below.

Translating sleeve
Inner Fixed Structure IFS
Thrust Reverser Actuation System TRAS
Door Opening System DOS

The thrust reverser is comprised of two halves that are mechanically independent.

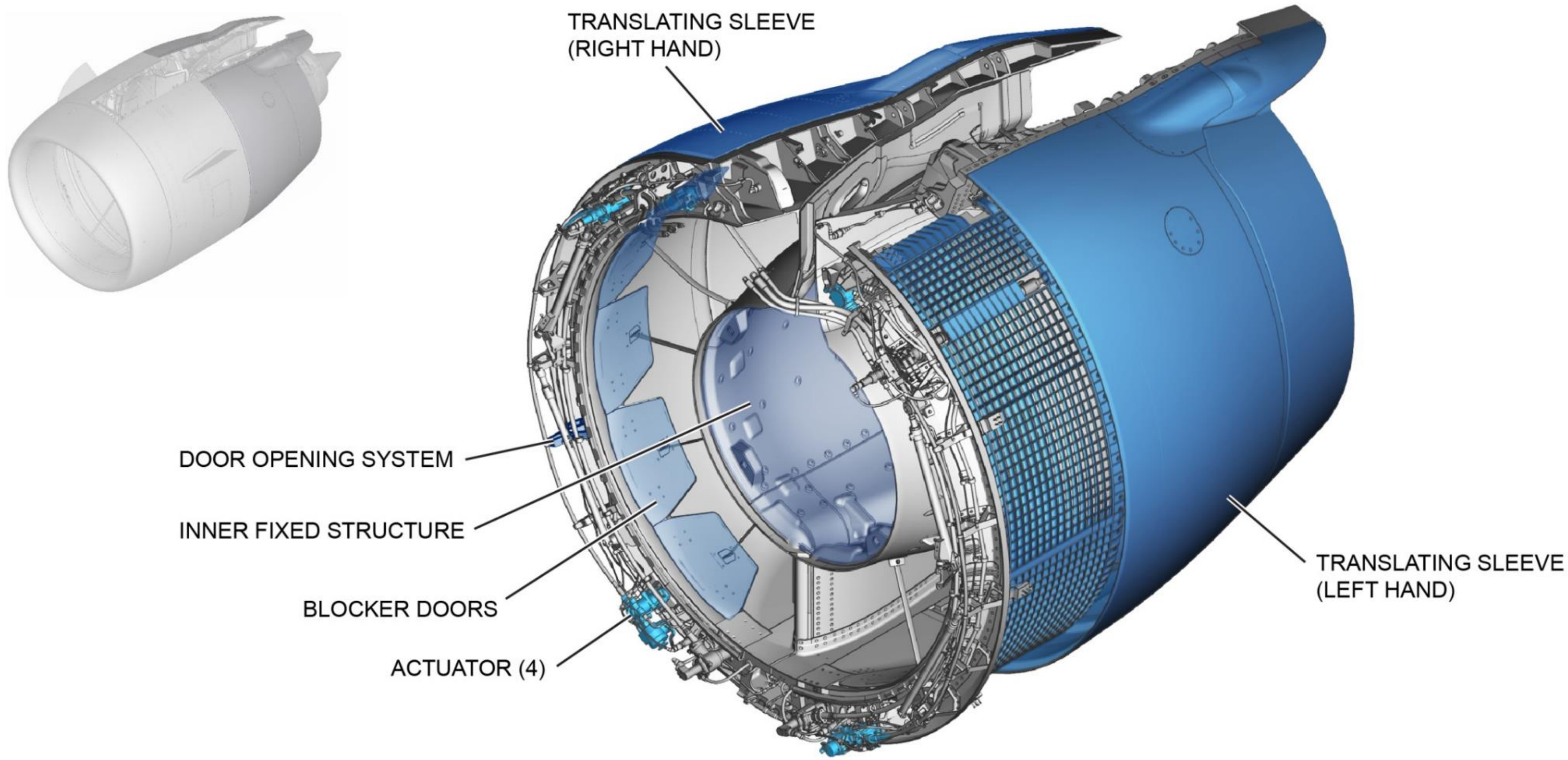
The halves hinge at the pylon, latching together along the bottom split line.

An Inner Fixed Structure (IFS) provides thrust reverser support and protects the engine’s core cases and externals.

The IFS forms the inner surface of the duct for fan bypass air.

An outer structure that includes a translating sleeve and blocker doors forms the outer surface of the fan bypass air duct.

The outer fan duct translating sleeve is normally stowed, providing uninterrupted fan air flow aft and producing the required thrust from the fan.


TRANSLATING SLEEVE
(RIGHT HAND)
DOOR OPENING SYSTEM
INNER FIXED STRUCTURE
BLOCKER DOORS
ACTUATOR (4)
TRANSLATING SLEEVE
(LEFT HAND)

THRUST REVERSER SYSTEM (Cont.)

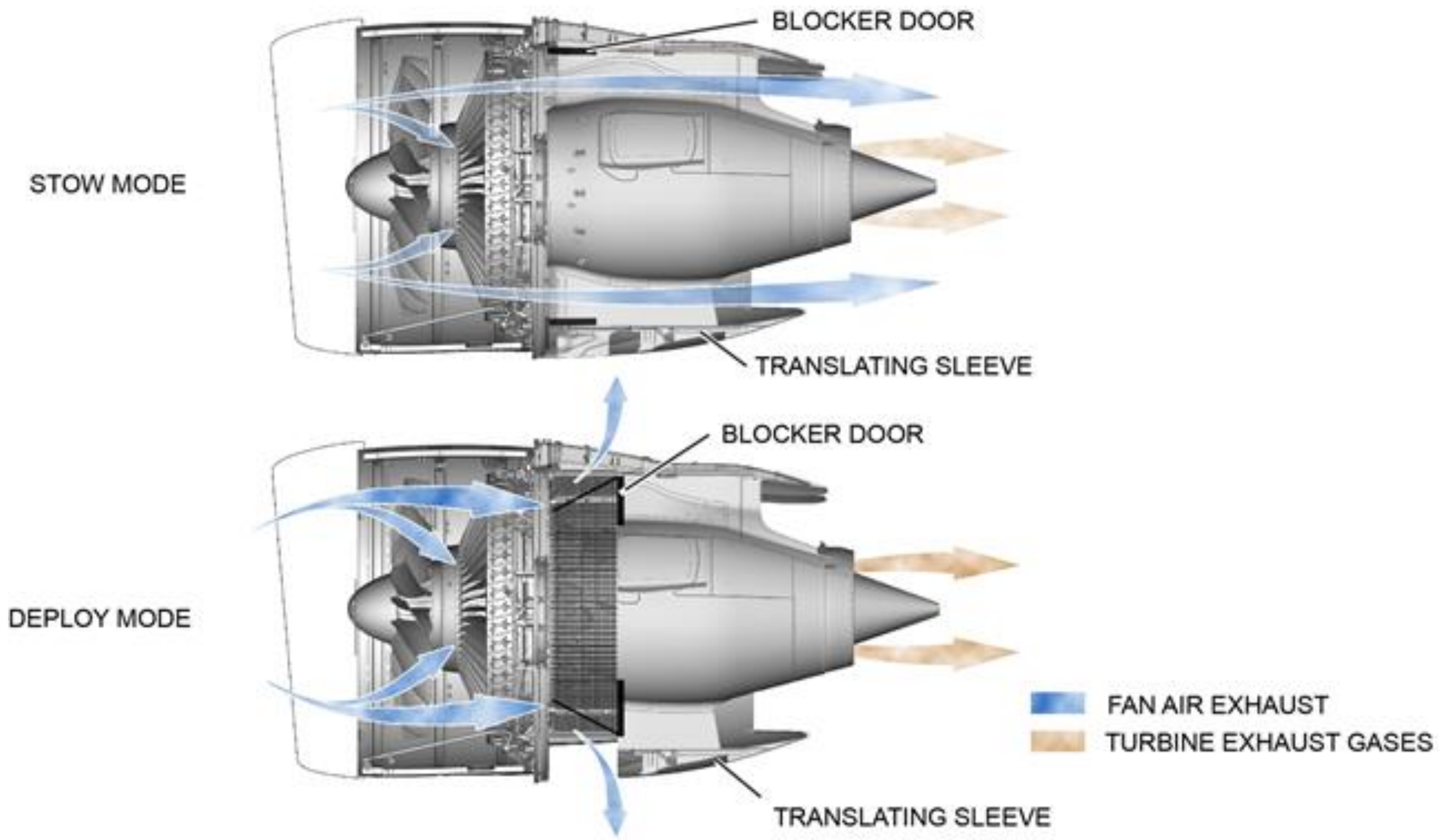
Upon landing, the thrust reverser is deployed, moving the translating sleeve aft and allowing blocker doors to rotate to a vertical position and block the fan air.

This action redirects the fan airflow through the thrust reverser cascades, sending it forward and outward in a controlled pattern that provides reverse thrust to help decelerate the aircraft.

The Thrust Reverser Actuation System (TRAS) is composed of two hydraulic linear synchronized actuators per side.

The actuators deploy and stow the reverser. Reverser operation is controlled by the EEC.

For ease in opening and closing, thrust reverser cowls are equipped with a Door Opening System (DOS).


BLOCKER DOOR
STOW MODE
TRANSLATING SLEEVE
BLOCKER DOOR
DEPLOY MODE
FAN AIR EXHAUST
TURBINE EXHAUST GASES
TRANSLATING SLEEVE

TRANSLATING SLEEVES

Purpose:

The translating sleeve is the movable thrust reverser component responsible for deploying the blocker doors and exposing the cascades.

Location:

The Thrust Reverser System has two translating sleeves which run aft of the engine fan case from the hinge beam to the latch beam.

Description:

The blocker doors redirect fan duct flow through the thrust reverser cascades.

The doors also form part of the outer fan duct's aerodynamic surface, as well as the acoustic lining of the outer fan duct wall.

A total of 10 blocker doors are used for a single thrust reverser, 5 per cowl half.

The upper and lower doors are unique in size and cannot be installed into any other position.

Two access panels are attached to the translating sleeve.

They provide access to fasteners that attach the TRAS actuators to the translating sleeve assembly.

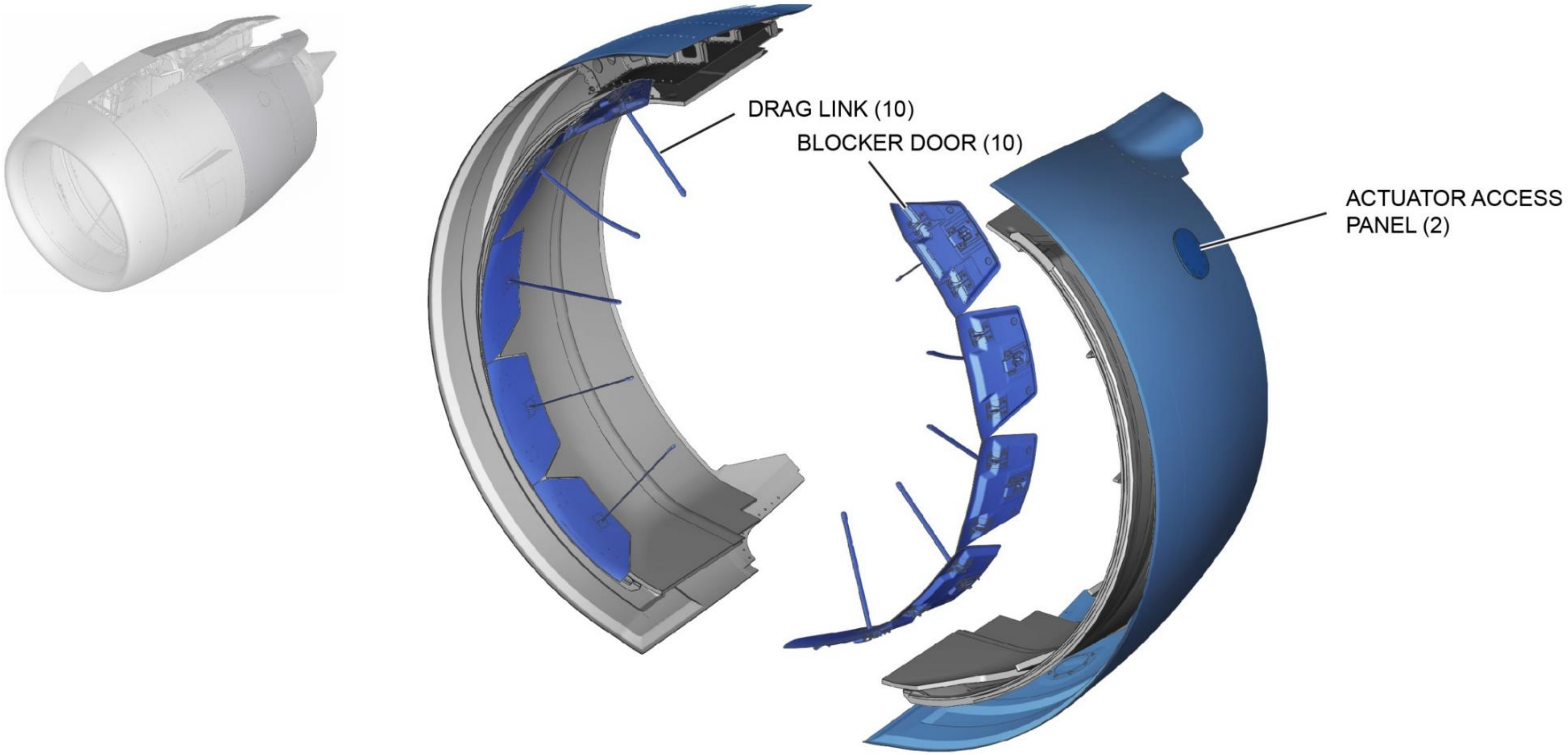
Operation:

Drag links aid in rotating and positioning the blocker doors into the fan duct, redirecting airflow through the thrust reverser cascades.

1. During activation of the thrust reverser, the translating sleeve slides aft.

2. As it slides, the blocker doors start to lift and rotate about their hinges due to the drag links attached to both the door and the Inner Fixed Structure.

3. Once the sleeve is fully deployed, the doors will be in their full upright position.


DRAG LINK (10)
BLOCKER DOOR (10)
ACTUATOR ACCESS
PANEL (2)

INNER FIXED STRUCTURE (IFS)

Purpose:

The inner surface of the thrust reverser is formed by the IFS, whose primary purpose is to provide thrust reverser hoop continuity and react to surge and burst pressures through the bumpers, latches and hinges.

Location:

The thrust reverser fixed structure covers the engine core, defines the core ventilation and fire zone, and forms the fan duct inner aerodynamic surface from the fan case exit to the core nozzle.

Description:

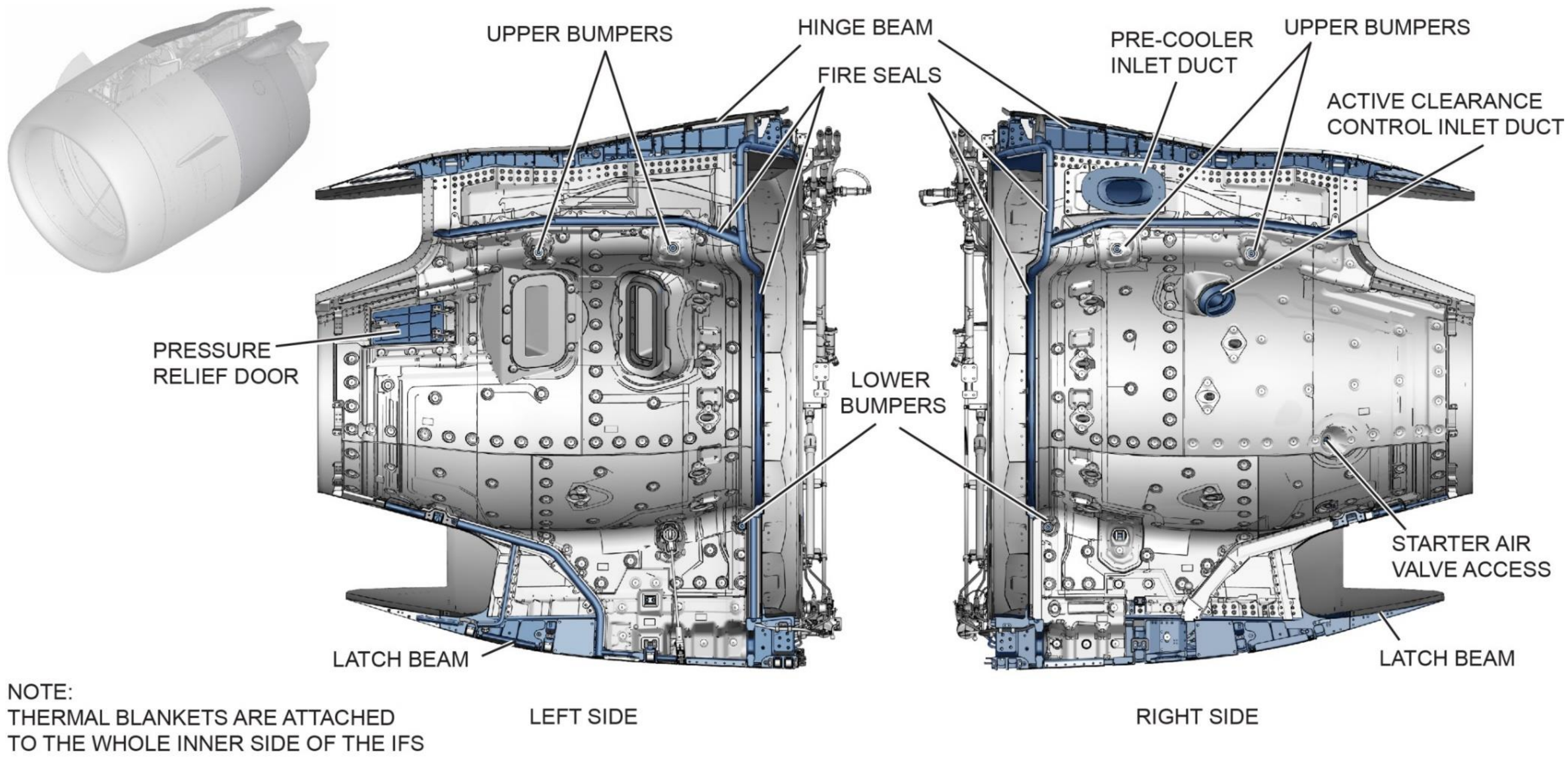
Thermal blankets are attached to the whole inner side of the IFS and provide a barrier against the hot engine compartment.

Operation:

Reverse thrust loads from the drag link fittings are transferred to a one-piece inner V-blade attached to the IFS panel.

Inner Fixed Structure components are shown below.

- Hinge beam
- Latch beam
- Fire seals
- Pressure relief door
- Bumpers
- Pre-cooler inlet duct
- Active Clearance Control inlet duct


UPPER BUMPERS
HINGE BEAM
FIRE SEALS
PRE-COOLER
INLET DUCT
UPPER BUMPERS
ACTIVE CLEARANCE
CONTROL INLET DUCT
PRESSURE
RELIEF DOOR
LOWER
BUMPERS
STARTER AIR
VALVE ACCESS
LATCH BEAM
LATCH BEAM
NOTE:
THERMAL BLANKETS ARE ATTACHED
TO THE WHOLE INNER SIDE OF THE IFS
LEFT SIDE
RIGHT SIDE

Inner Fixed Structure (IFS) (Cont.)

Hinge Beams

Purpose:

The hinge beams provide a structural connection between the IFS and transcowl through two tracks integrated into the beams.

Location:

The aluminium beams attach directly to the IFS and interface with the transcowl via the primary and secondary tracks integrated into the beams.

Description:

The hinge beam extends the length of the upper bifurcation and connects the two reverser halves to the pylon via three hinge beam clevises and one floating hinge.

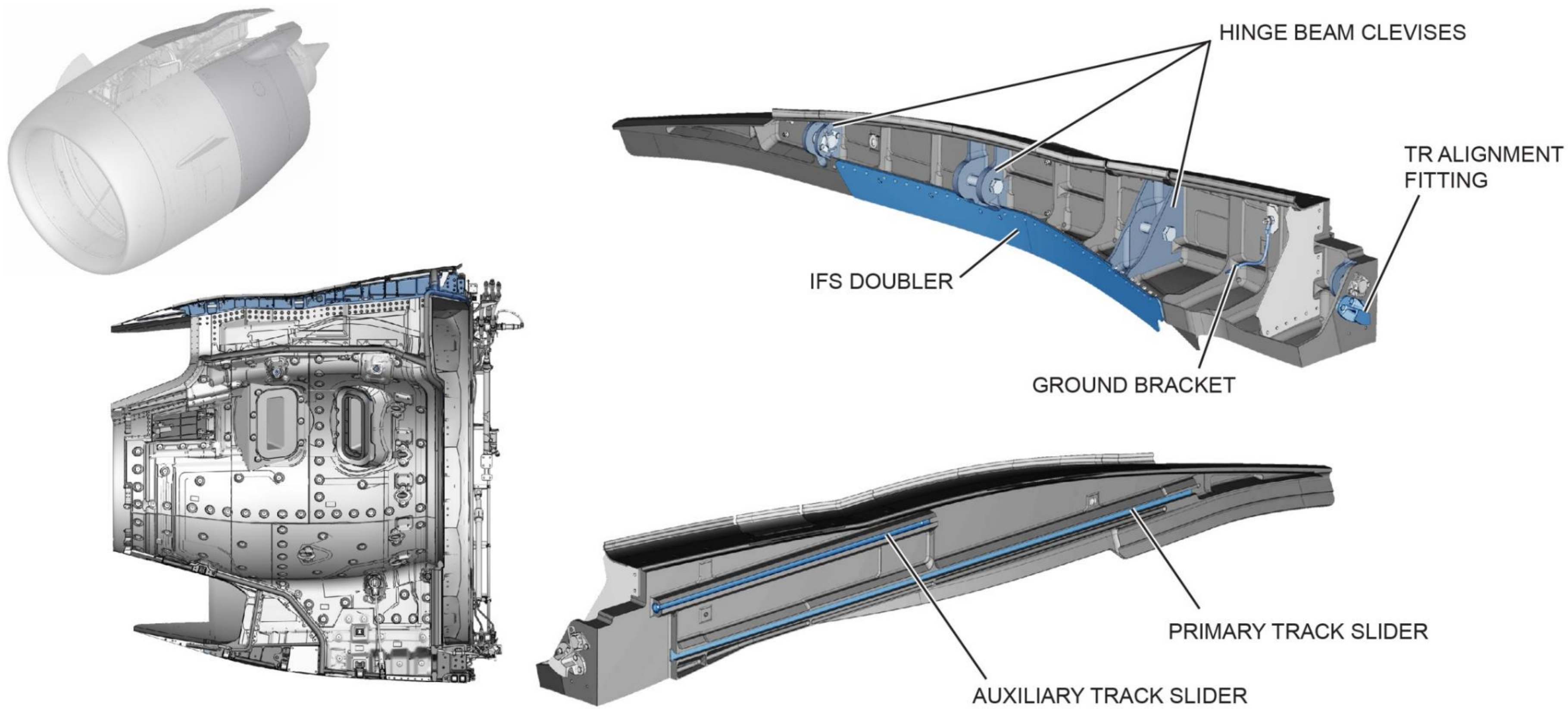
Operation:

The integrated tracks provide a means for the sleeve to slide during deployment of the reverser.

Additionally, the beams provide a mounting surface for the aft cascade ring, and react to hoop and radial loads from the aft cascade ring.

Hinge beam features are listed below.

- Hinge beam clevises
- Floating hinge clevis
- TR alignment fitting
- Primary and secondary track sliders
- IFS doubler
- Ground bracket


HINGE BEAM CLEVISES
TR ALIGNMENT
FITTING
IFS DOUBLER
GROUND BRACKET
PRIMARY TRACK SLIDER
AUXILIARY TRACK SLIDER

Inner Fixed Structure (IFS) (Cont.)

Latch Beams

Purpose:

Latch beams provide a structural connection between the IFS and transcowl.

Location:

The beams attach directly to the IFS.

Description:

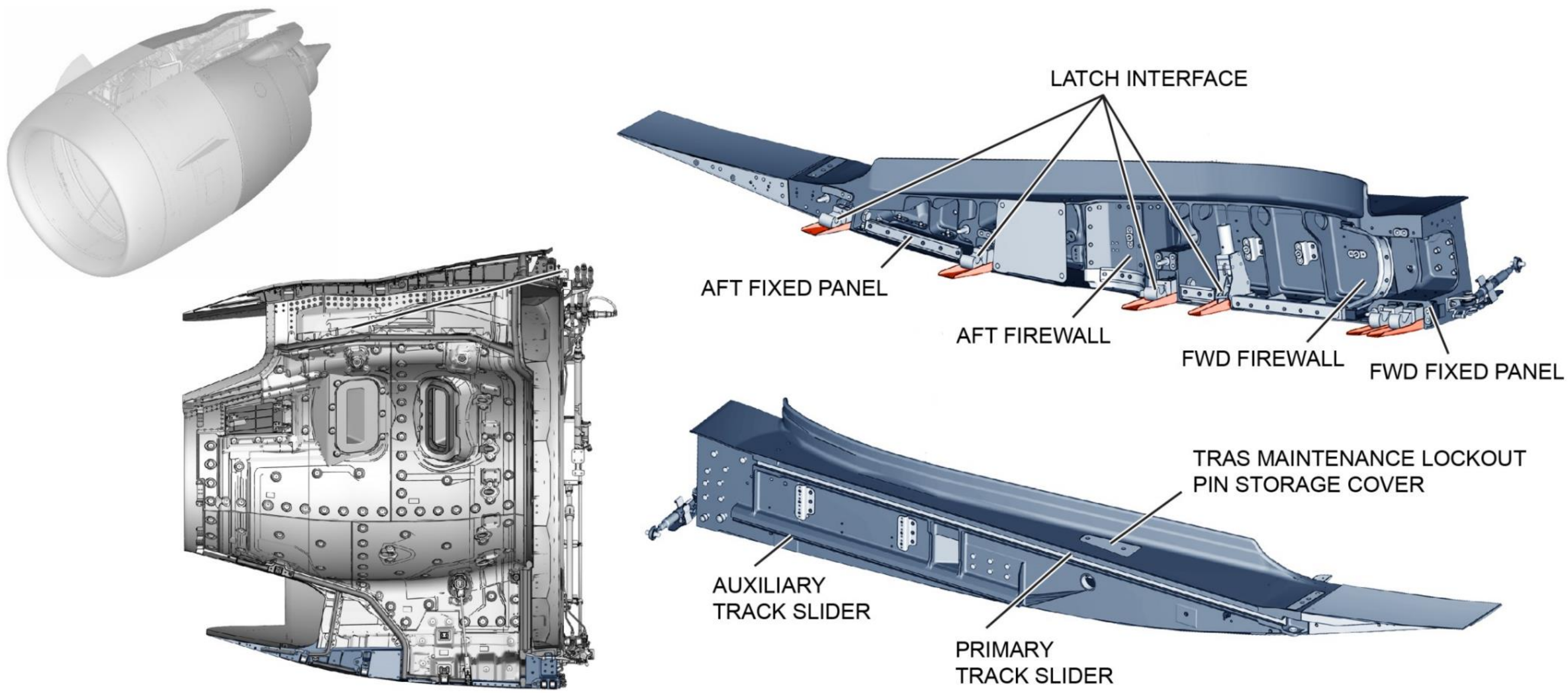
The aluminium beams feature integrated primary and secondary tracks that interface with the transcowl.

Five latches and a Bifurcation Latch System (BLS) are part of each latch beam.

Each beam extends the length of the lower bifurcation and connects the two reverser halves via the latches, also serving as a mounting surface for the TRAS third lock.

Latch beam features are listed below.

- Latches and latch interface
- Primary and auxiliary track sliders
- Latch access panel
- Forward and aft fixed panel and firewall
- Closure assist fitting
- IFS attach Interface
- Stow pin or cover


LATCH INTERFACE
AFT FIXED PANEL
AFT FIREWALL
FWD FIREWALL
FWD FIXED PANEL
TRAS MAINTENANCE LOCKOUT
PIN STORAGE COVER
AUXILIARY
TRACK SLIDER
PRIMARY
TRACK SLIDER

Inner Fixed Structure (IFS) (Cont.)

Latches

Purpose:

Latches integral to the beams provide structural hoop load transfer to the nacelle, and offer quick access to the engine core.

The latches also provide resistance to loads that might otherwise cause the thrust reverser to disengage or open during the flight cycle.

Location:

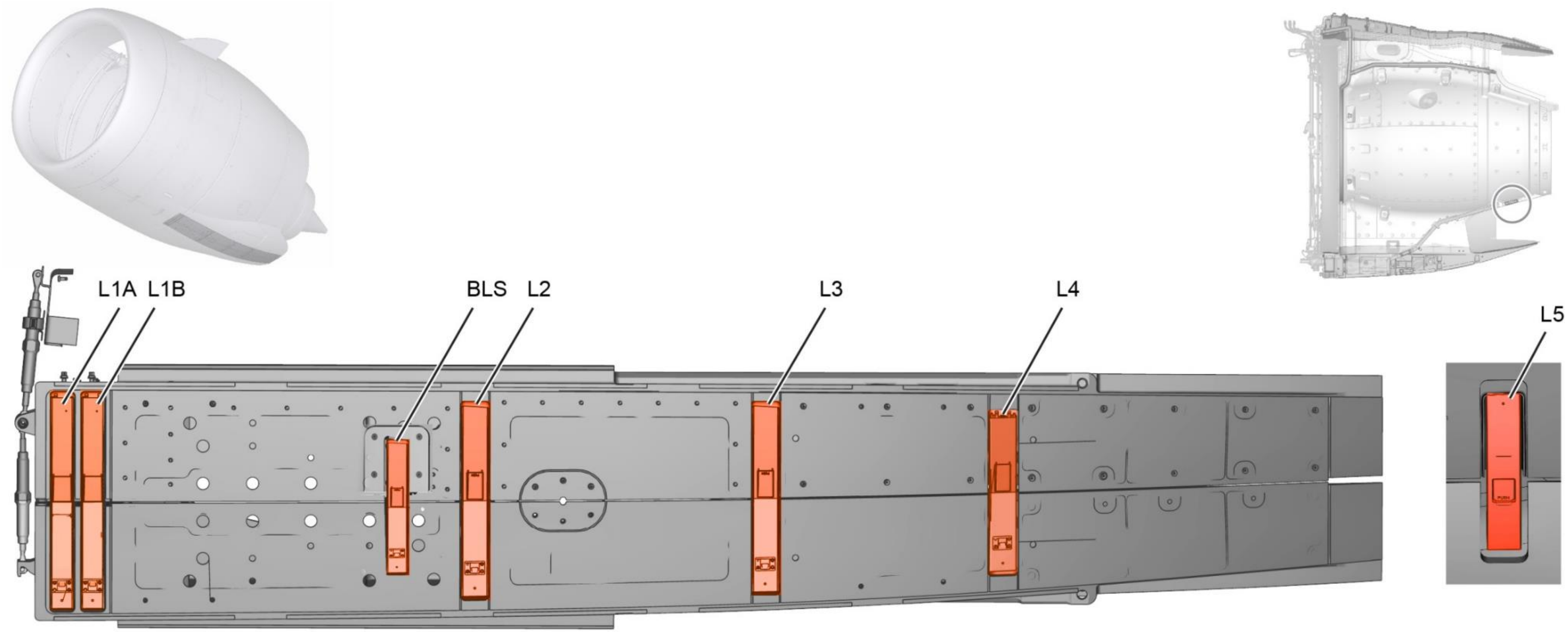
The table shows locations for all latches.

Description:

Except for the BLS latch that is part of the Bifurcation Latch System, all latches are double hooked to ensure each one is fail safe in the event of single element failure.

In addition to the latches, a closure assist rod helps close the cowling.

Latch	Location
L1A, L1B, BLS, L2	Forward fixed panel
L3, L4	Aft fixed panel
L5	IFS panel



BOTTOM VIEW

NOTE:
L5 IS LOCATED ON THE IFS PANEL

Inner Fixed Structure (IFS) (Cont.)

Closure Assist Assembly

Purpose:

The Closure Assist Assembly consists of a turnbuckle that is used to draw the door together before engaging the latches.

Location:

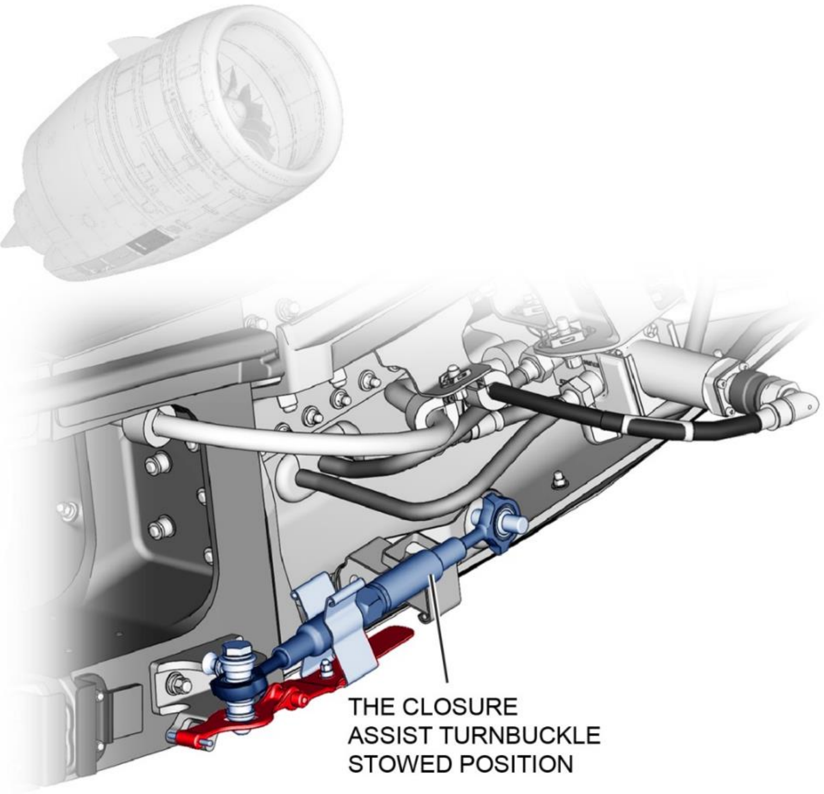
The assembly is located on the front of the left thrust reverser at 6:00.

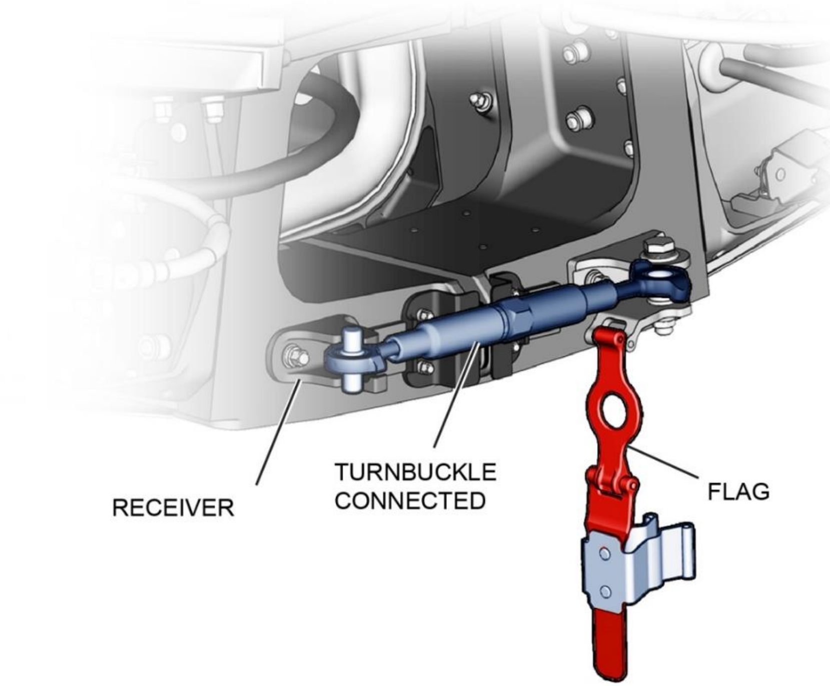
Description:

An eye on one end of the turnbuckle allows it to pivot so the pin engages the opposite cowling.

Once engaged, the turnbuckle is turned manually to draw the two doors together.

The turnbuckle is stowed after use.


THE CLOSURE
ASSIST TURNBUCKLE
STOWED POSITION


RECEIVER
TURNBUCKLE
CONNECTED
FLAG

Inner Fixed Structure (IFS) (Cont.)

Bumpers

Purpose:

Bumpers provide a hoop load path to resist the crushing pressure of the fan air stream upon the barrel sections and bifurcations.

Location:

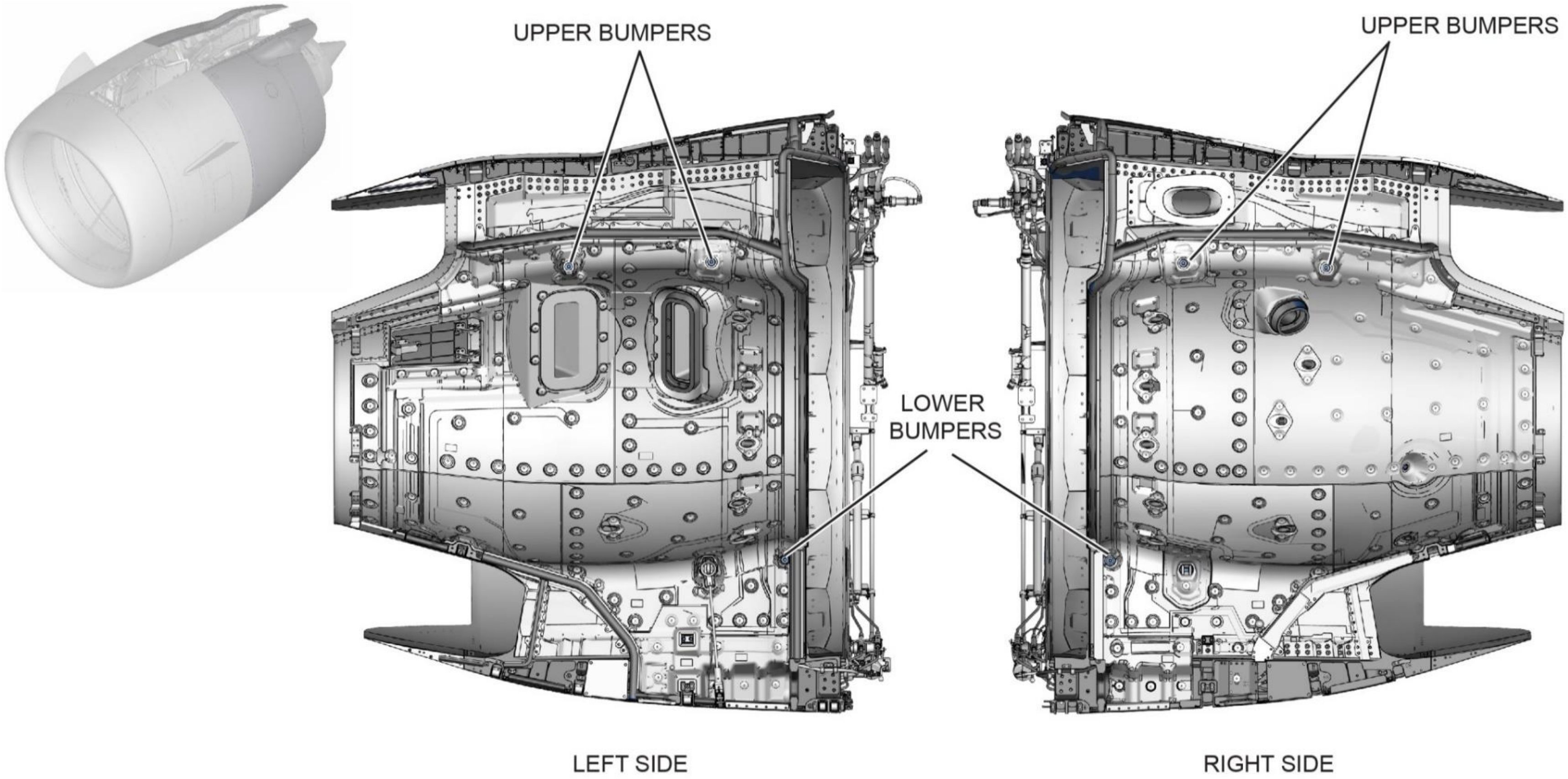
Three bumpers are located at the radius corner intersections between the thrust reverser barrel section and the bifurcation area.

Description:

Bumpers are aluminium components that act as deflection limiters to maintain a correct fit of the ducts to the engine, and to assist alignment as the two cowling halves are closed.

The upper bumper includes a compression rod to compensate for the larger gap between the two cowls.

The compression rod extends across the underside of the pylon from the upper aft and forward radius corner intersections.


UPPER BUMPERS
UPPER BUMPERS
LOWER
BUMPERS
LEFT SIDE
RIGHT SIDE

Inner Fixed Structure (IFS) (Cont.)

Bifurcation Latch System (BLS)

Purpose:

The Bifurcation Latching System is used to limit the deflection of the fixed structure, and to maintain the structural integrity in the event of a burst air duct.

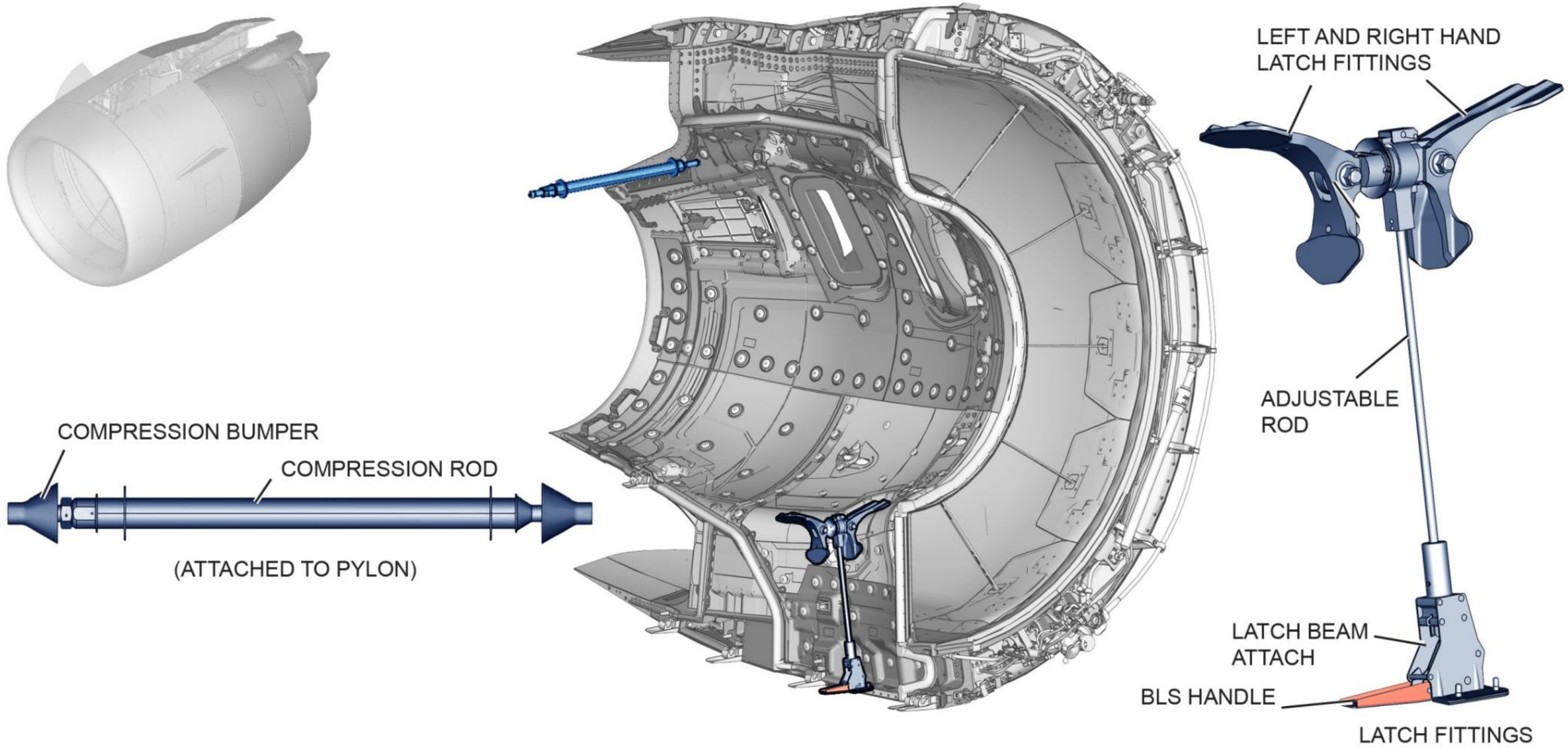
Description:

The Bifurcation Latch System resembles the other bumpers, but also incorporates a locking feature to keep it engaged.

The BLS handle is accessed through the latch access door.

The system is a pull-open, push-closed design with a baulking feature to visually indicate positive engagement of the latch.

The latch is adjustable to ensure proper engagement. When closed, the handle remains parallel to the engine centreline.


LEFT AND RIGHT HAND
LATCH FITTINGS
COMPRESSION BUMPER
COMPRESSION ROD
(ATTACHED TO PYLON)
ADJUSTABLE
ROD
LATCH BEAM
ATTACH
BLS HANDLE
LATCH FITTINGS

Bifurcation Latch System (Cont.)

Operation:

When engaged, the bifurcation latch uses a rod and cam mechanism to insert a locking pin through the latch.

As the IFS closes, a pin on the left side is inserted into a receiver located on the right side.

The pin/latch mechanism is locked together using a rod.

The rod is inserted through the pin by turning and pushing up the BLS lever.

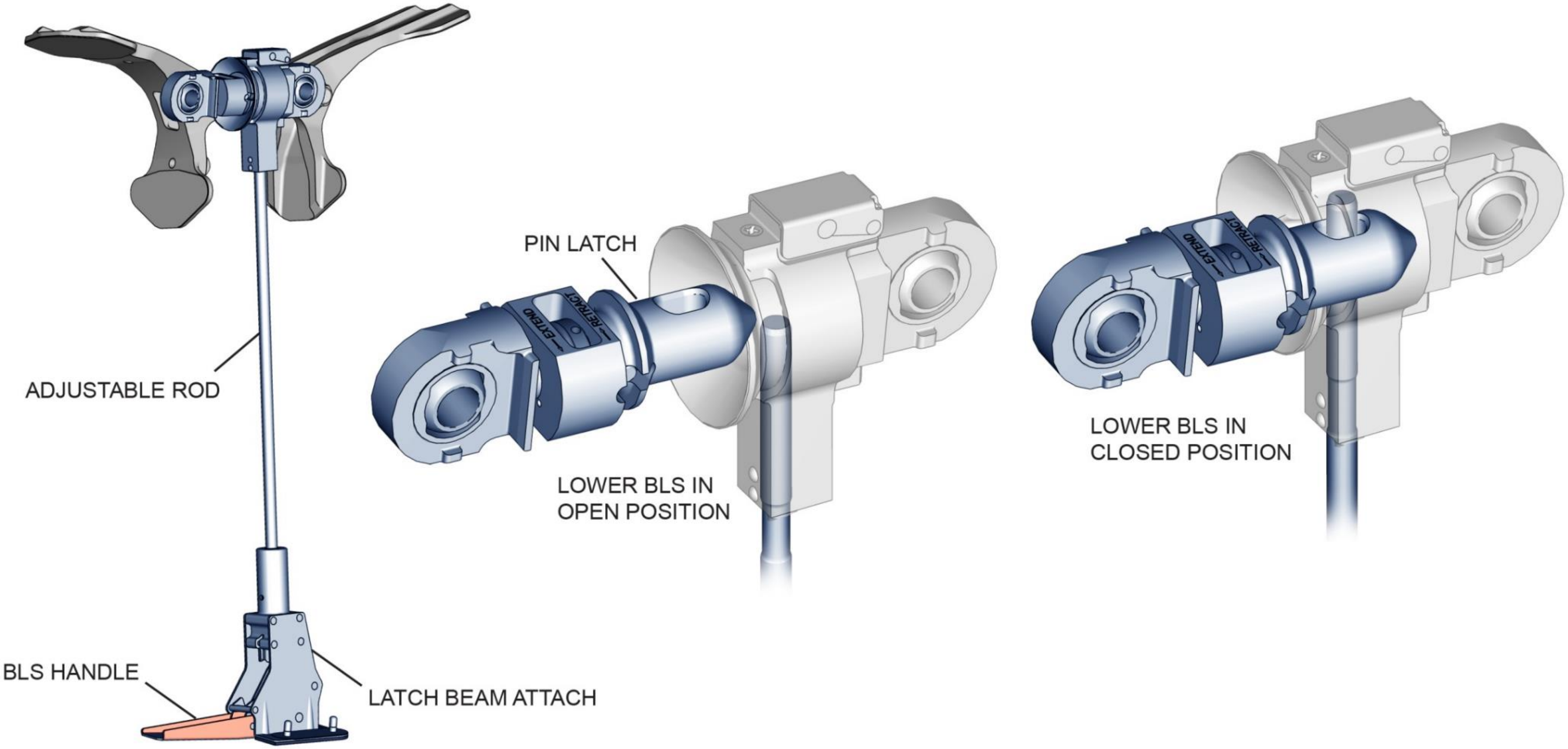
The bifurcation latch is locked in place when the lever is aligned with the IFS by pushing the lever in.

The pin latch mechanism is adjustable up to 0.635 cm (1/4 in.) in either direction.

The bifurcation latch lever is painted red, providing a visual indication of the position.

For the bifurcation latch to properly engage, the lever should be positioned correctly.

The latch access panel cannot be closed if there is interference with the latch handle.



ADJUSTABLE ROD
BLS HANDLE
LATCH BEAM ATTACH
PIN LATCH
RETRACT
EXTEND
LOWER BLS IN
OPEN POSITION
LOWER BLS IN
CLOSED POSITION

Inner Fixed Structure (IFS) (Cont.)

Fire Seals

Purpose:

Fire seals provide fire protection and aerodynamic fit.

Location:

The seals are located circumferentially on the Inner Fixed Structure.

Description:

Fire protection consists of fireproof barriers and seal arrangements.

The fire seals prevent the escape of flames from a fire zone and prevent air or fluids from entering.

The seals are made of a soft, compressible fireproof material. The “turkey feather” barrier seal is made of metal.

Pressure Relief Door

Purpose:

The pressure relief door provides adequate pressure relief when core cavity pressure exceeds the design limit.

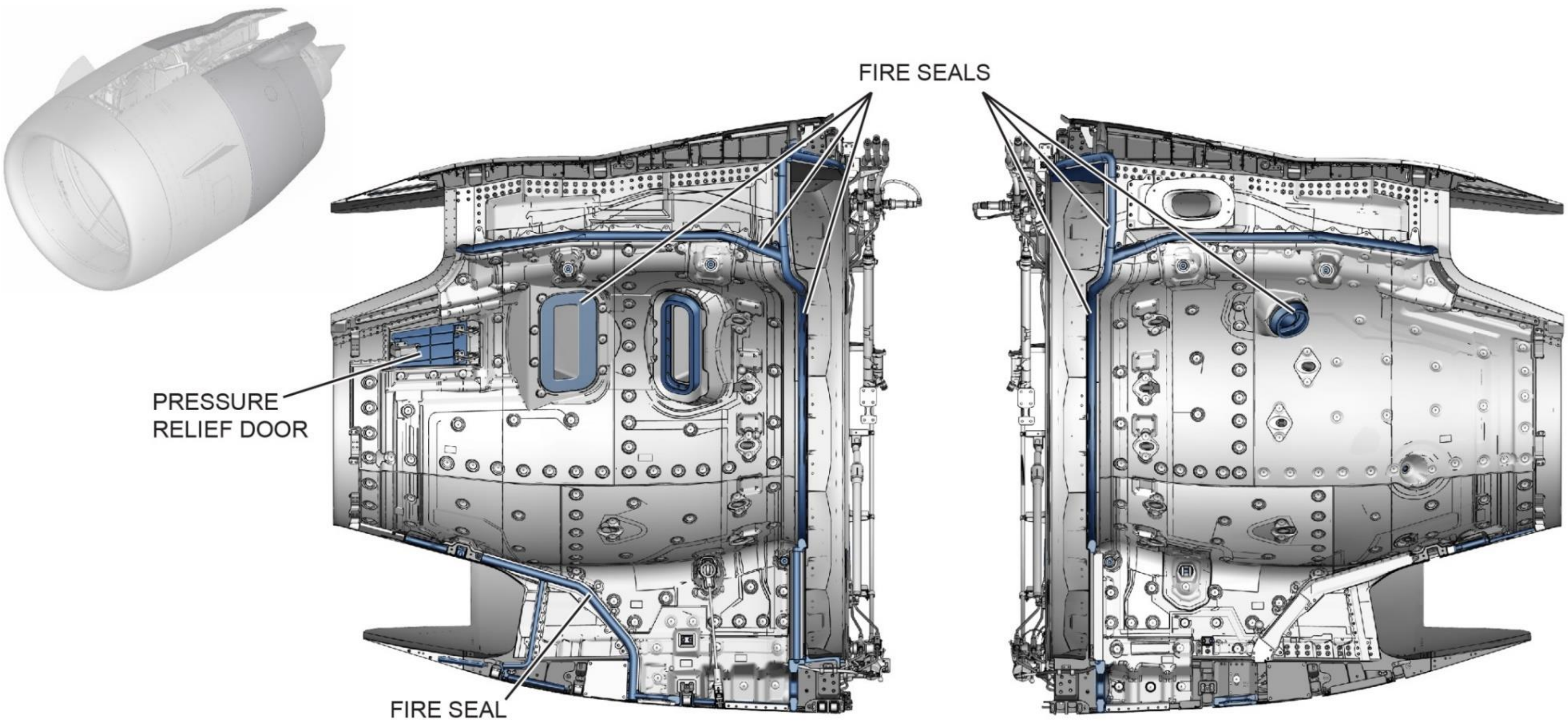
Location:

The pressure relief door is on the left IFS at 9:00.

Description:

The door must open to provide adequate pressure relief when core cavity pressure goes above the designed cavity pressure.

The pressure relief door opens if cavity pressure exceeds the latch release pressure, such as in the event of a burst cooling air duct.



NOTE:
THERMAL BLANKETS ARE ATTACHED
TO THE WHOLE INNER SIDE OF THE IFS

Inner Fixed Structure (IFS) (Cont.)

Torque Box Assembly

Purpose:

The torque box is a curved beam with torsional stiffness that supports the thrust reverser actuators, cascades, hinge beam and latch beam.

Location:

The torque box runs from the hinge beam to the latch beam.

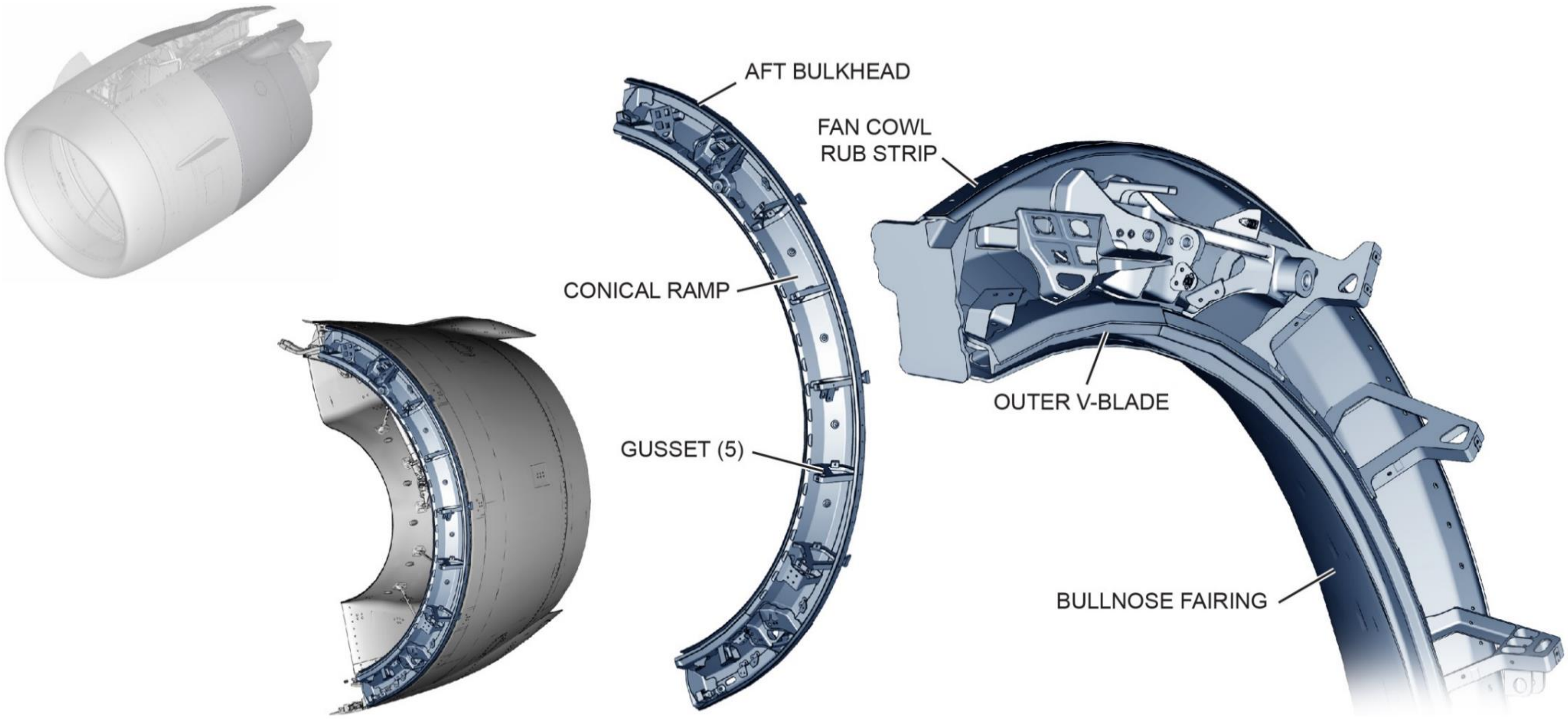
Description:

The torque box consists of these parts:

- aft bulkhead
- conical ramp
- bullnose fairing
- Outer V-Blade OVB
- rub strip shim
- fan cowl rub strip.

Operation:

Torque from the actuators is transferred to the beams through the gussets. Loads from the Door Opening System (DOS) and Hold Open Rods (HORs) are transferred to the torque box through a DOS fitting and brackets attached to the bulkhead.


AFT BULKHEAD
FAN COWL
RUB STRIP
CONICAL RAMP
OUTER V-BLADE
GUSSET (5)
BULLNOSE FAIRING

Cascade Array

Purpose:

The cascade array turns fan airflow forward and sideways.

Location:

Each cascade has a forward attachment at the torque box and an aft attachment at the aft cascade ring.

Description:

The fastener attachment pattern allows for limited interchangeability between cascade locations while ensuring the cascade cannot be installed backwards.

Each engine has seven cascade boxes.

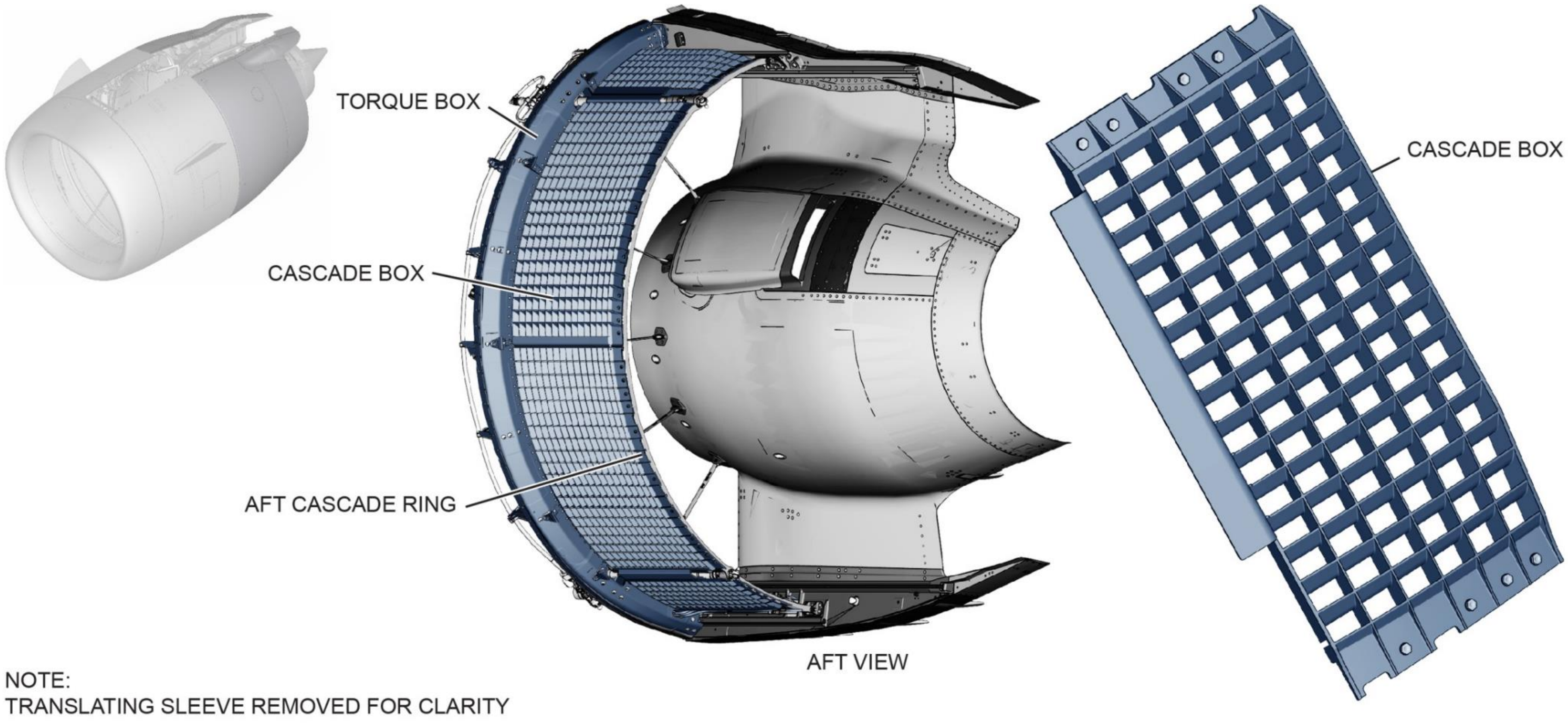
Operation:

Reverse thrust is achieved when the transcowl deploys the blocker doors and exposes an array of carbon-fibre composite cascade boxes.

The forward-turning component of each cascade contributes to reverse thrust.

The combination of forward-turning and side-turning angles produces an efflux pattern that prevents these effects:

- reverse thrust airflow re-ingestion into the inlet
- cross engine inlet re-ingestion
- fuselage impingement
- impingement on the aircraft’s control surfaces and high-lift devices.



TORQUE BOX
CASCADE BOX
AFT CASCADE RING
AFT VIEW
CASCADE BOX
NOTE:
TRANSLATING SLEEVE REMOVED FOR CLARITY

Aft Cascade Ring (ACR)

Purpose:

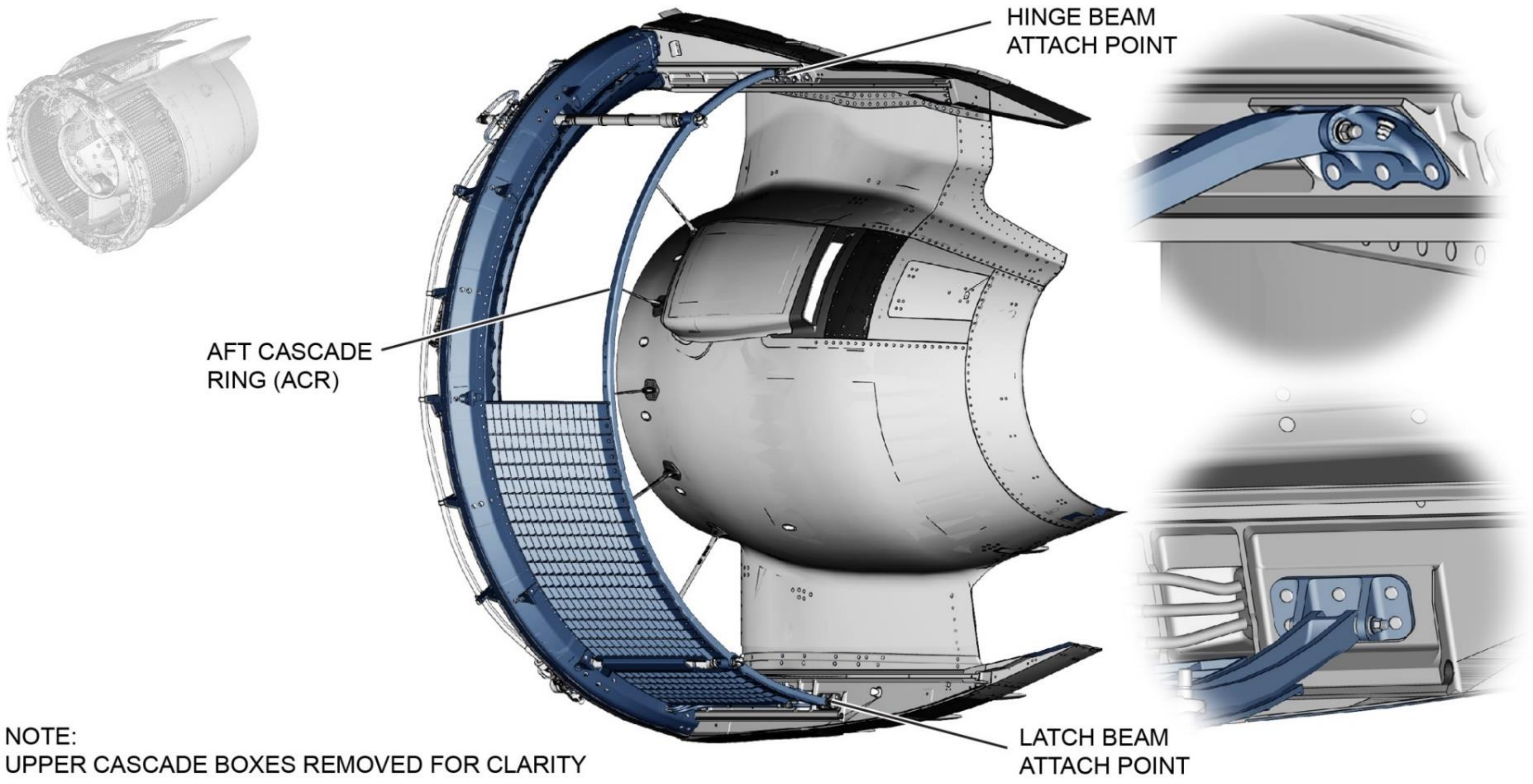
The Aft Cascade Ring provides aft support for the cascade segments.

Location:

The ACR beam runs from the hinge beam to the latch beam along the aft edge of the cascades.

Description:

The ACR is a curved, open-section metal beam that transmits aerodynamic and dynamic loads from the cascades to the hinge and latch beams.


HINGE BEAM
ATTACH POINT
AFT CASCADE
RING (ACR)
LATCH BEAM
ATTACH POINT
NOTE:
UPPER CASCADE BOXES REMOVED FOR CLARITY

Hold Open Rods (HORs)

Purpose:

HORs prop open the thrust reverser to provide a safe environment for performing maintenance work on the engine.

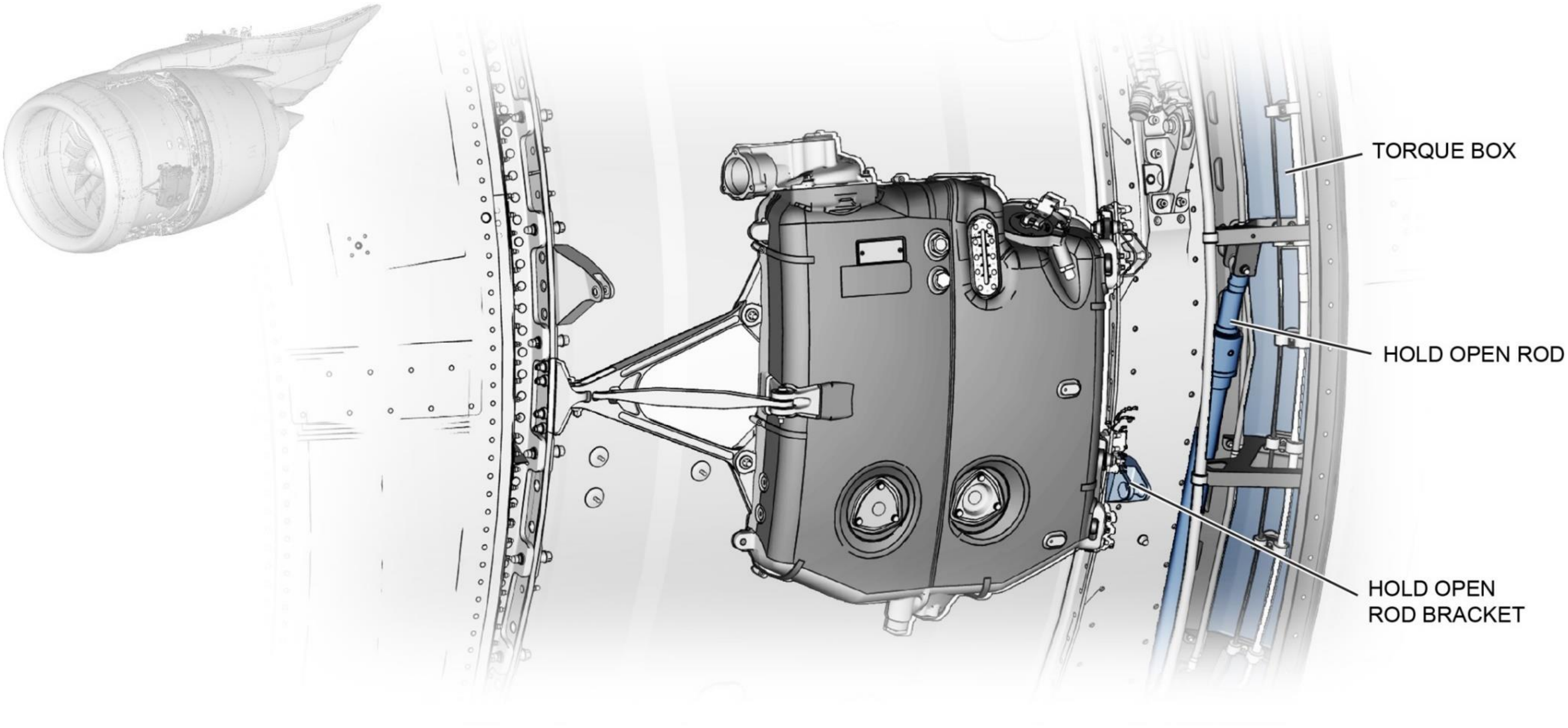
Location:

HORs are attached to the thrust reverser torque box and the engine’s fan case.

Description:

Each thrust reverser has one Hold Open Rod.

Hold Open Rods are stowed on the torque box when not in use.


TORQUE BOX
HOLD OPEN ROD
HOLD OPEN
ROD BRACKET

Thrust Reverser Actuation System (TRAS)

A Hydraulic Control Unit (HCU) provides isolation and directional control of hydraulic fluid used for thrust reverser actuation.

The thrust reverser is comprised of two halves that are mechanically decoupled, and which hinge from the pylon.

The halves latch together along the bottom split line. Upon deployment, translating sleeves move aft, causing blocker doors to rotate and block the fan air.

This action redirects the fan flow through the thrust reverser cascades, sending air forward and outward in a controlled plume and providing reverse thrust.

Two hydraulic linear synchronized actuators per side deploy and stow the reverser.

The thrust reverser can be used for either engine position as long as the cascade pattern is changed to match airflow control requirements.

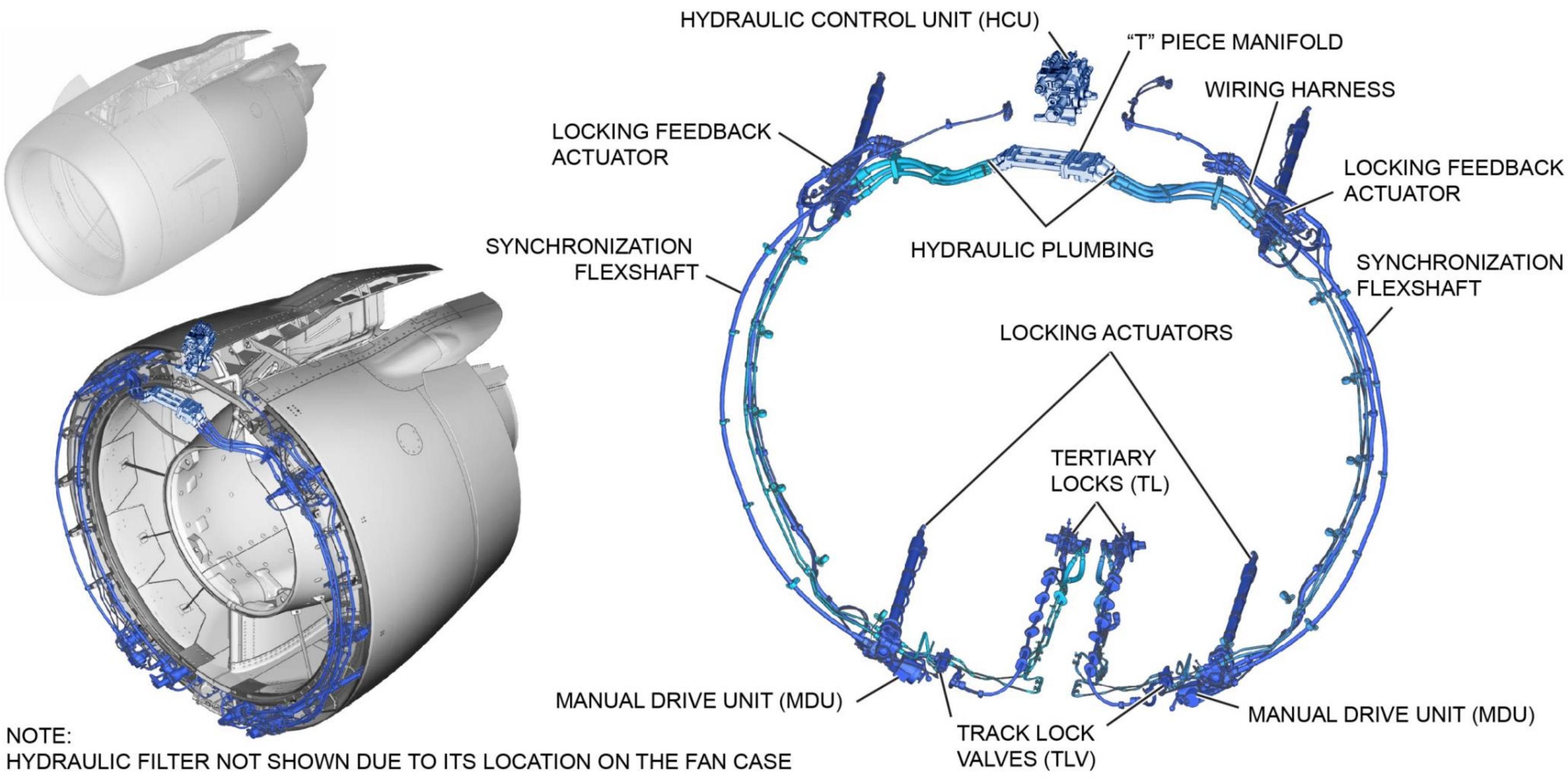
Each half of the thrust reverser has two actuator units that include an integral locking mechanism and proximity switch, and one actuator with a Linear Variable Differential Transformer (LVDT) for reverser position feedback.

The thrust reverser also includes a “third line of defence” provided by two fully independent Tertiary Locks (TL).

Reversers can be deployed and stowed manually on the ground by using the Manual Drive Units (MDU) located on the lower actuators.

Components for this system are listed below.

- Hydraulic Control Unit HCU
- Filter module assembly
- T-piece manifold
- Locking actuator (2)
- Locking feedback actuator (2)
- Manual Drive Unit (2) MDU
- Synchronization flex shaft (2)
- Track Lock Valve (2) TLV
- Tertiary Lock (2) TL
- Wiring harness and plumbing up to pylon interfaces



NOTE:
HYDRAULIC FILTER NOT SHOWN DUE TO ITS LOCATION ON THE FAN CASE

Thrust Reverser Actuation System (TRAS) (Cont.)

Hydraulic Control Unit

Purpose:

The Hydraulic Control Unit (HCU) controls the locking, unlocking and translating operation of the actuators.

Location:

The HCU is in the pylon upper spar.

Description:

The HCU contains the Isolation Control Valve (ICV) and the Directional Control Valve (DCV), and their respective solenoids.

The ICV and DCV are operated from dual channel solenoid pilot valves upon a signal from the EEC.

A manual inhibition function provides these capabilities:

- dispatches inoperative thrust reversers
- prevents inadvertent activation of the ICV
- provides additional safety during ground maintenance activities.

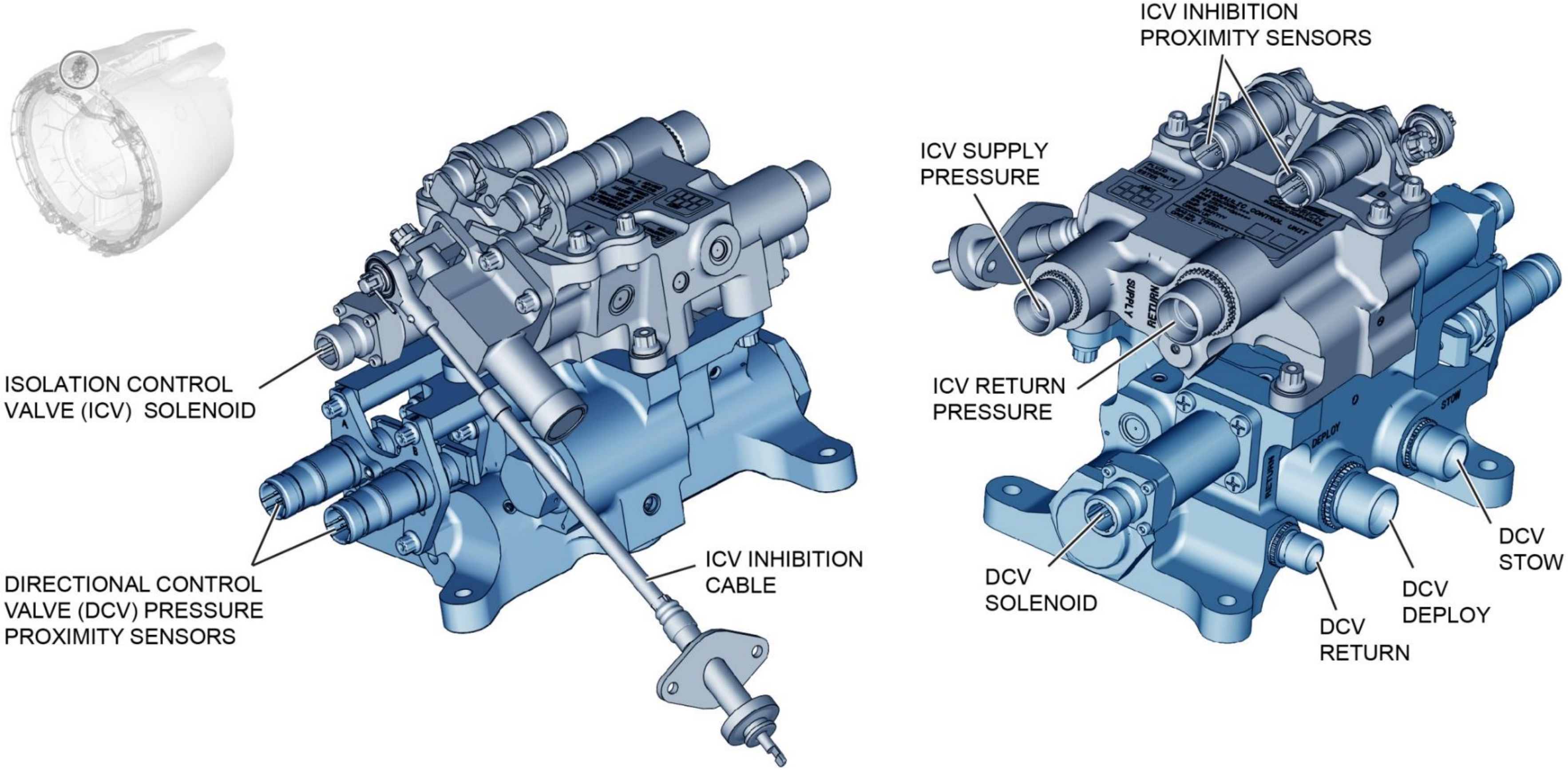
Deactivation is provided by an inhibit lever and inhibit pin. Proximity sensors detect the lever's position.

Operation:

The isolation valve isolates the entire downstream system from the aircraft hydraulic pressure supply, unless an arming signal is received.

Hydraulic fluid to power the TRAS is supplied from the aircraft system.

The directional control valve uses a spool valve to regulate the direction of pressure application to the actuators in order to achieve the unlock, deploy, stow and relock sequence. DCV position signal comes from proximity sensors.


ISOLATION CONTROL
VALVE (ICV) SOLENOID
DIRECTIONAL CONTROL
VALVE (DCV) PRESSURE
PROXIMITY SENSORS
ICV INHIBITION
CABLE
ICV INHIBITION
PROXIMITY SENSORS
ICV SUPPLY
PRESSURE
ICV RETURN
PRESSURE
DCV
SOLENOID
DCV
RETURN
DCV
DEPLOY
DCV
STOW

Thrust Reverser Actuation System (TRAS) (Cont.)

Filter Module Assembly

Purpose:

The filter module assembly protects downstream TRAS components from debris that may be present in the aircraft hydraulic system.

Location:

The assembly is mounted in the pylon above the lower aft pylon fairing.

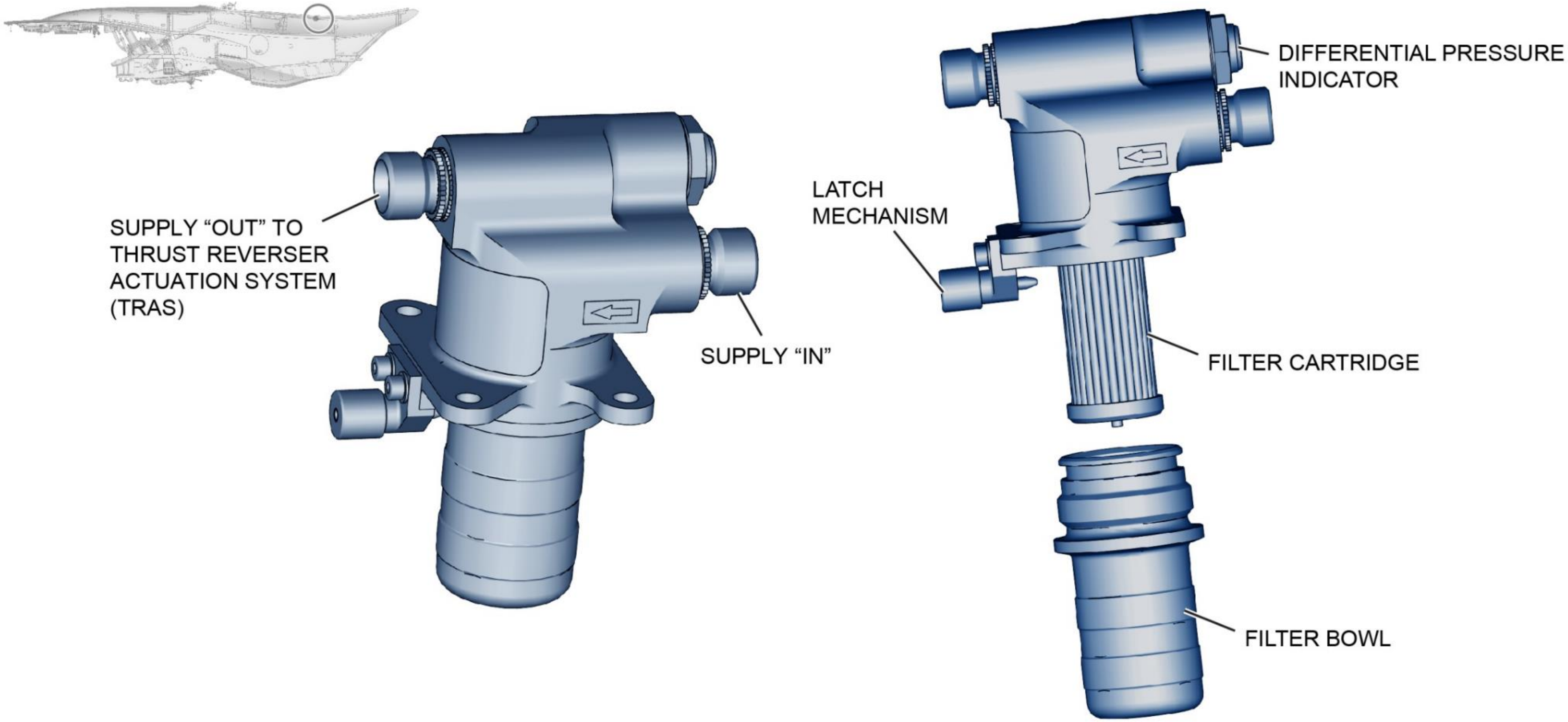
Description:

The 15-micron filtration system is installed on the inlet side of the thrust reverser supply.

A differential pressure indicator, or “red button” pops out to visually indicate when the filter is clogged.

An automatic shutoff valve allows removal and installation of the filter without significant loss of hydraulic fluid from the system.

In this instance the system will still function, but will be slow to deploy or stow.



SUPPLY “OUT” TO THRUST REVERSER ACTUATION SYSTEM (TRAS)
SUPPLY “IN”
LATCH MECHANISM
DIFFERENTIAL PRESSURE INDICATOR
FILTER CARTRIDGE
FILTER BOWL

Thrust Reverser Actuation System (TRAS) (Cont.)

T-piece Manifold

Purpose:

The T-piece manifold provides a path for hydraulic system pressure to be ported from the Hydraulic Control Unit to the TRAS actuators.

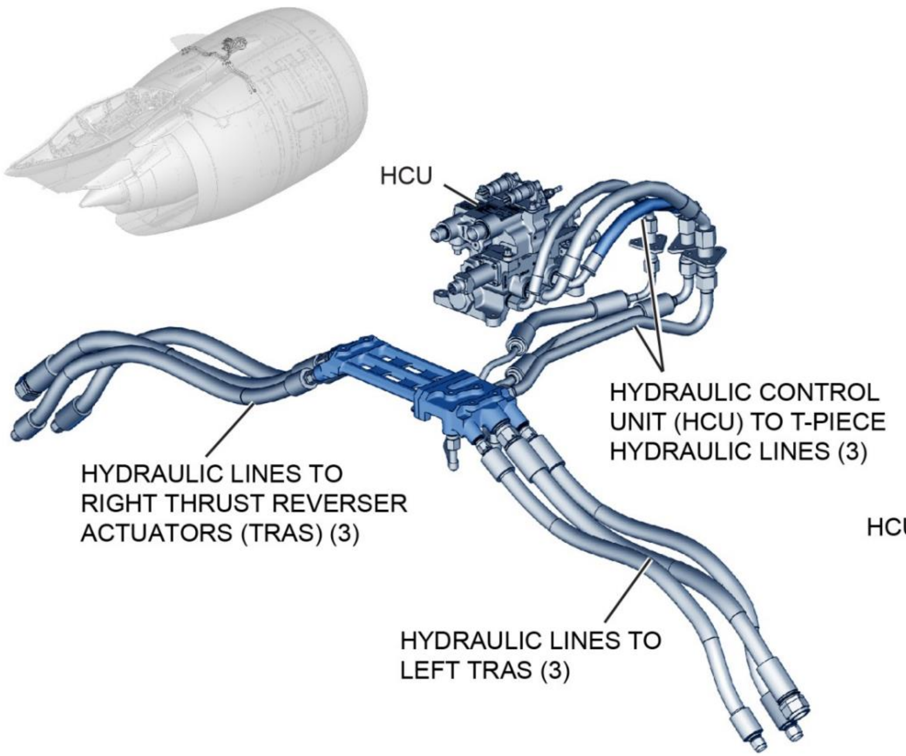
Location:

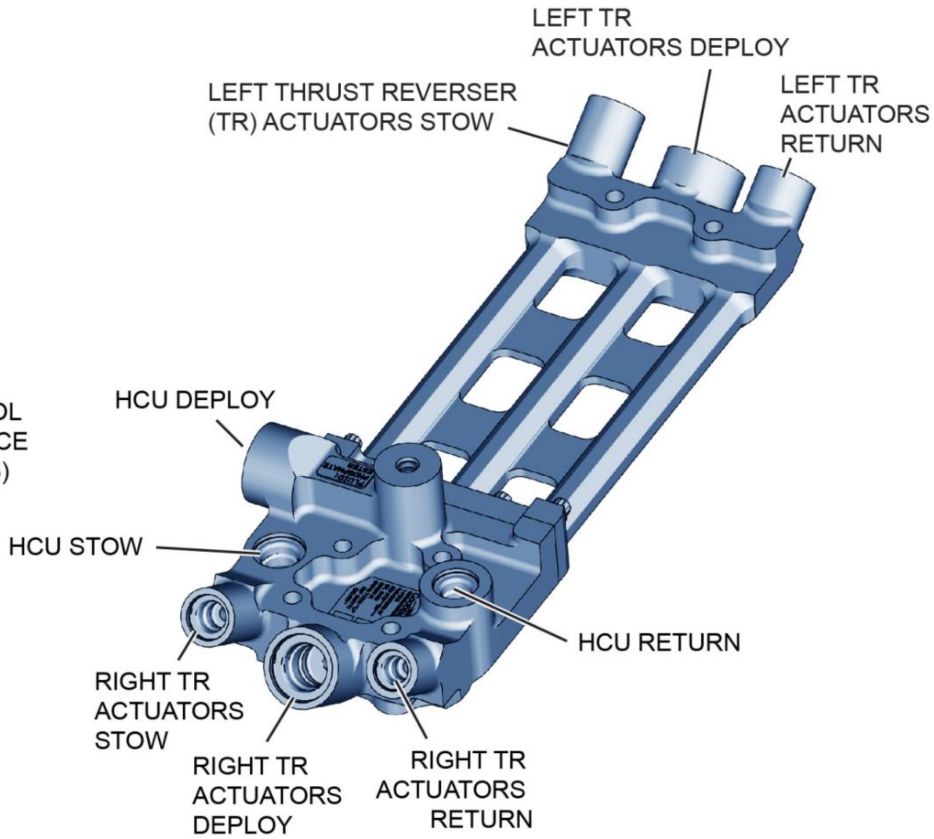
The manifold is located in the forward section of the pylon.

Description:

The T-piece manifold has a total of six lines that distribute hydraulic fluid to the thrust reverser actuators.

Three of the lines are located on the left and three are on the right.


HCU
HYDRAULIC CONTROL UNIT (HCU) TO T-PIECE HYDRAULIC LINES (3)
HYDRAULIC LINES TO RIGHT THRUST REVERSER ACTUATORS (TRAS) (3)
HYDRAULIC LINES TO LEFT TRAS (3)


LEFT TR ACTUATORS DEPLOY
LEFT THRUST REVERSER (TR) ACTUATORS STOW
LEFT TR ACTUATORS RETURN
HCU DEPLOY
HCU STOW
HCU RETURN
RIGHT TR ACTUATORS STOW
RIGHT TR ACTUATORS DEPLOY
RIGHT TR ACTUATORS RETURN

Thrust Reverser Actuation System (TRAS) (Cont.)

Locking Actuator

Purpose:

The actuators deploy and stow the reverser sleeves and also lock them in the stowed position.

Location:

The actuators are mounted on the thrust reverser torque box at approximately 5:00 and 7:00.

Description:

The lower actuators each incorporate an integral, hydraulically released mechanical locking element.

A manual lock release provision facilitates manual translation of the reverser via manual drive units located on each side.

Lock release and manual drive access is gained by opening the fan cowl doors.

Both the lower and upper actuator in each half of the thrust reverser incorporate a hydraulically released mechanical element.

A proximity sensor switch is included in the locking mechanism of each actuator to provide the electrical feedback of lock engagement status to the EEC.

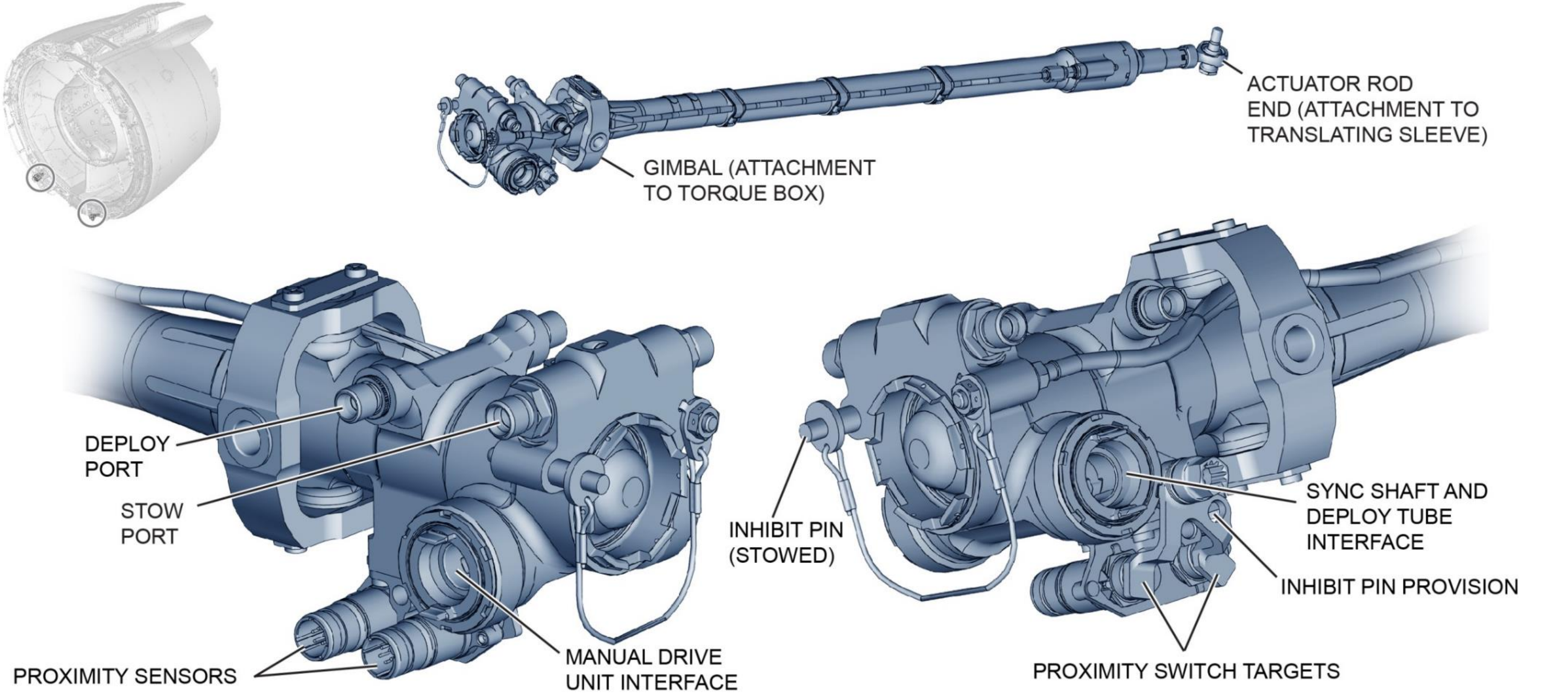
An inhibit handle is provided to lock out the actuator during maintenance.

A gimbal allows for thrust and torsional motion of the actuator during operation.

Operation:

The actuators are operated hydraulically using worm wheels and flex drive shafts.

When the command is given by the crew through the movement of the throttle levers, and when additional conditions are met, the reverser deploys and stows.


ACTUATOR ROD
END (ATTACHMENT TO
TRANSLATING SLEEVE)
GIMBAL (ATTACHMENT
TO TORQUE BOX)
DEPLOY
PORT
STOW
PORT
INHIBIT PIN
(STOWED)
SYNC SHAFT AND
DEPLOY TUBE
INTERFACE
INHIBIT PIN PROVISION
PROXIMITY SENSORS
MANUAL DRIVE
UNIT INTERFACE
PROXIMITY SWITCH TARGETS

Thrust Reverser Actuation System (TRAS) (Cont.)

Locking Feedback Actuator

Purpose:

The actuators are used to deploy and stow the reverser sleeves, lock them in the stowed position, and provide feedback of sleeve position.

Location:

The actuators are mounted on the thrust reverser torque box at approximately 1:00 and 11:00.

Description:

The actuators each incorporate and integral, hydraulically released mechanical locking element.

Electrical feedback of thrust reverser position is accomplished by means of an LVDT integrated into each upper actuator.

An inhibition handle is provided to lock out the actuator during maintenance.

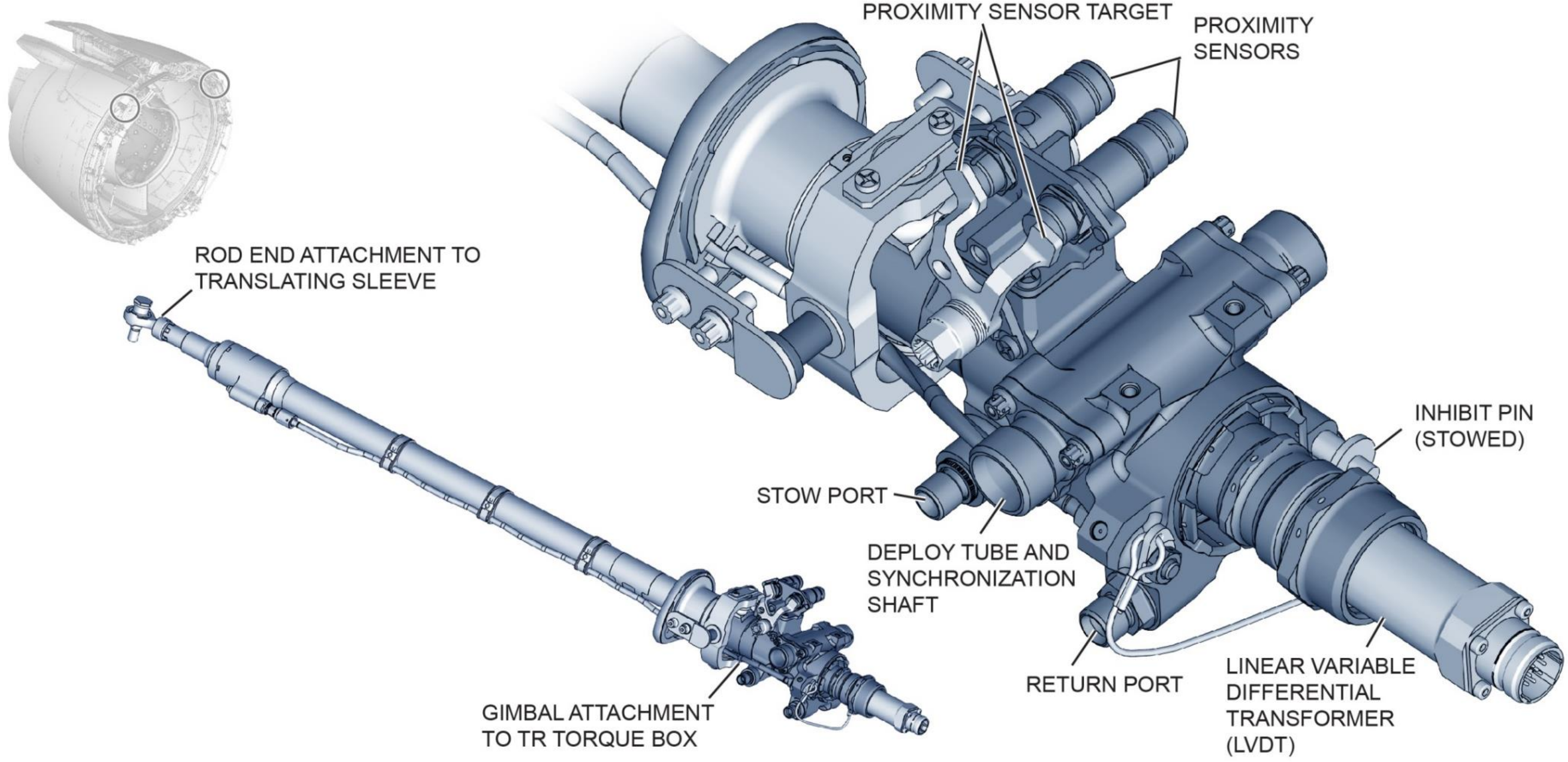
A gimbal allows for thrust and torsional motion of the actuator during operation.

Operation:

The actuators are operated hydraulically using worm wheels and flex drive shafts.

When the command is given by the crew through the movement of the throttle levers, and when additional conditions are met, the reverser deploys and stows.

A single channel LVDT device on each upper actuator can provide true dual channel thrust reverser position feedback to the EEC via the mechanical coupling between the upper and lower actuators.


PROXIMITY SENSOR TARGET
PROXIMITY SENSORS
ROD END ATTACHMENT TO TRANSLATING SLEEVE
INHIBIT PIN (STOWED)
STOW PORT
DEPLOY TUBE AND SYNCHRONIZATION SHAFT
RETURN PORT
LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)
GIMBAL ATTACHMENT TO TR TORQUE BOX

Thrust Reverser Actuation System (TRAS) (Cont.)

Manual Drive Unit (MDU)

Purpose:

The manual drive unit allows manual translation of the thrust reverser during maintenance.

Location:

The MDU is mounted onto both lower locking actuators.

Description:

The MDU is only used when aircraft is in maintenance configuration.

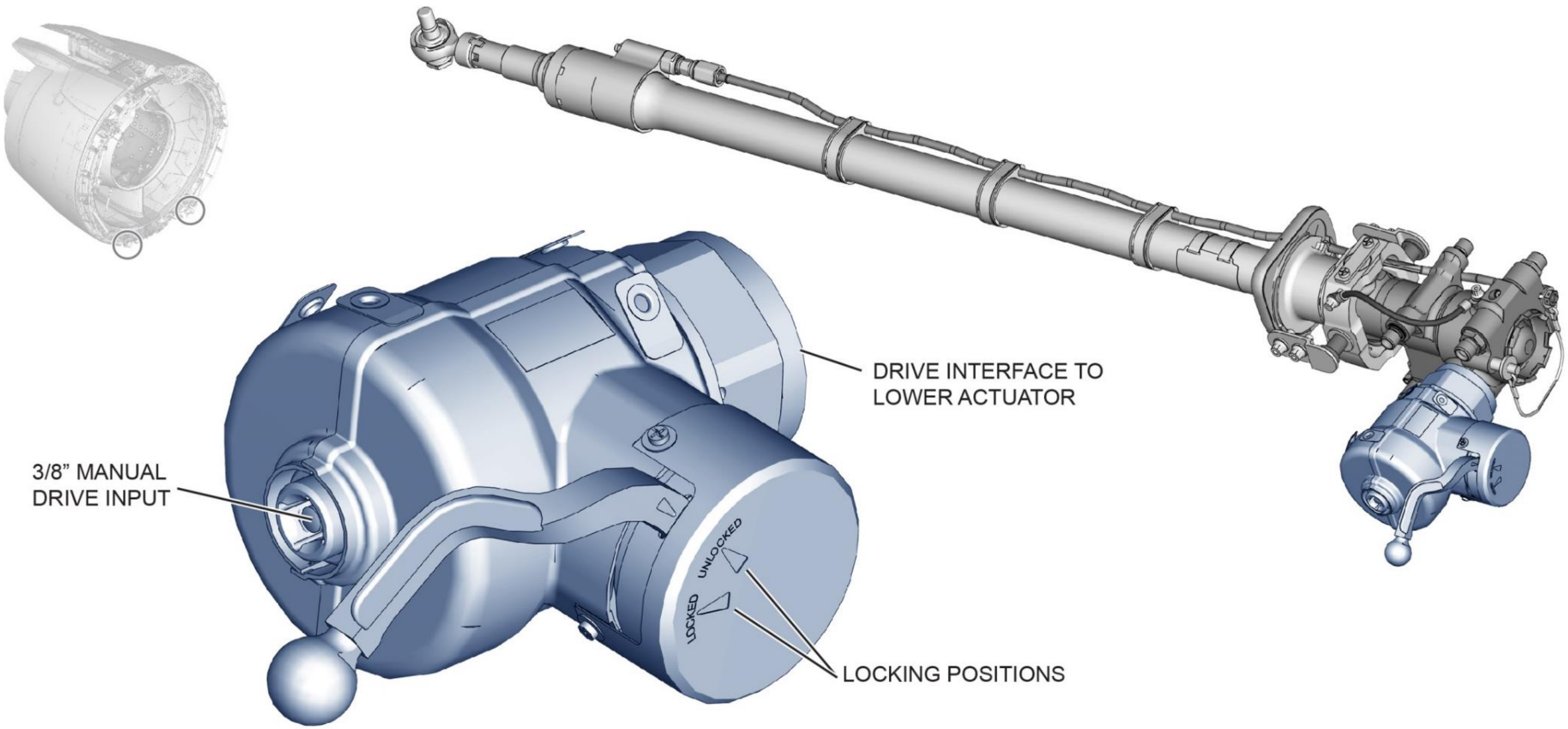
Maximum operational speed of the MDU is 600 rpm.

Operation:

A 3/8” square drive tool input enables manual rotation of the TRAS synchronization system and translates the sleeve as required.

A clutch torque limiter in the MDU that provides over torque protection is installed to prevent damage to TRAS components during TRAS manual operation.

A baulking feature on the fan cowl pushes the lock lever to the locked position in the event the MDU lock lever is left unlocked.


DRIVE INTERFACE TO
LOWER ACTUATOR
3/8" MANUAL
DRIVE INPUT
UNLOCKED
LOCKED
LOCKING POSITIONS

Thrust Reverser Actuation System (TRAS) (Cont.)

Synchronization Flex Shafts

Purpose:

Flex shafts provide TRAS synchronization by connecting the upper locking feedback actuator to the lower locking actuator on each thrust reverser half.

Location:

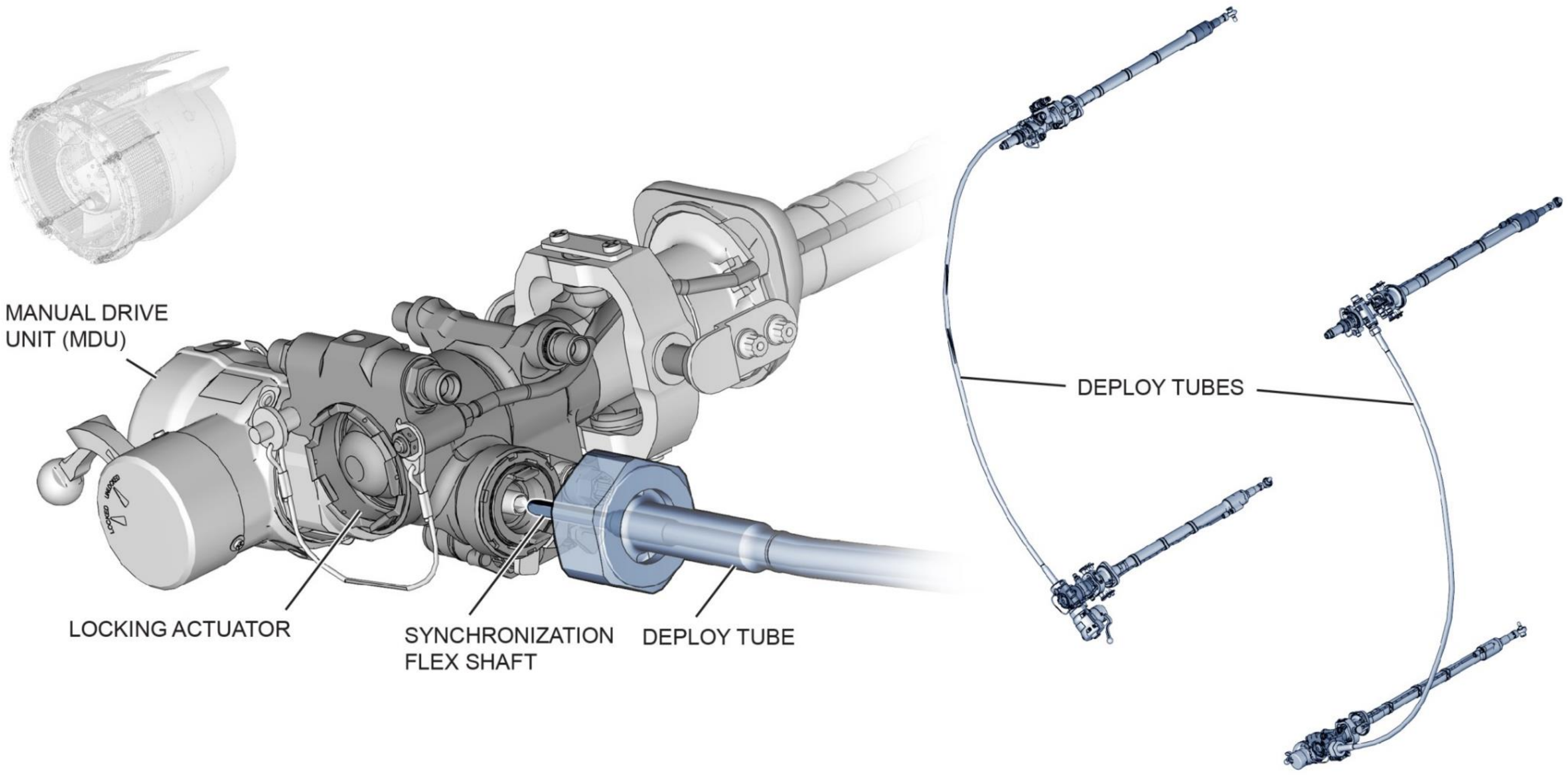
The synchronization shafts are located inside the deploy tubes which are mounted to the thrust reverser torque box.

Description:

Each cowl half has one flex shaft.

The deploy tube provides a path for the TRAS hydraulic system to pressurize during deploy and stow sequence.

The flex shaft square drive interfaces with the actuator drive system and is secured by the deploy tube to the actuator.


MANUAL DRIVE
UNIT (MDU)
LOCKING ACTUATOR
SYNCHRONIZATION
FLEX SHAFT
DEPLOY TUBE
DEPLOY TUBES

Thrust Reverser Actuation System (TRAS) (Cont.)

Track Lock Valve (TLV)

Purpose:

The Track Lock Valve controls the locking and unlocking of the tertiary locks.

Location:

The TLV is mounted to a bracket that is attached to the torque box of each thrust reverser door at approximately 6:00.

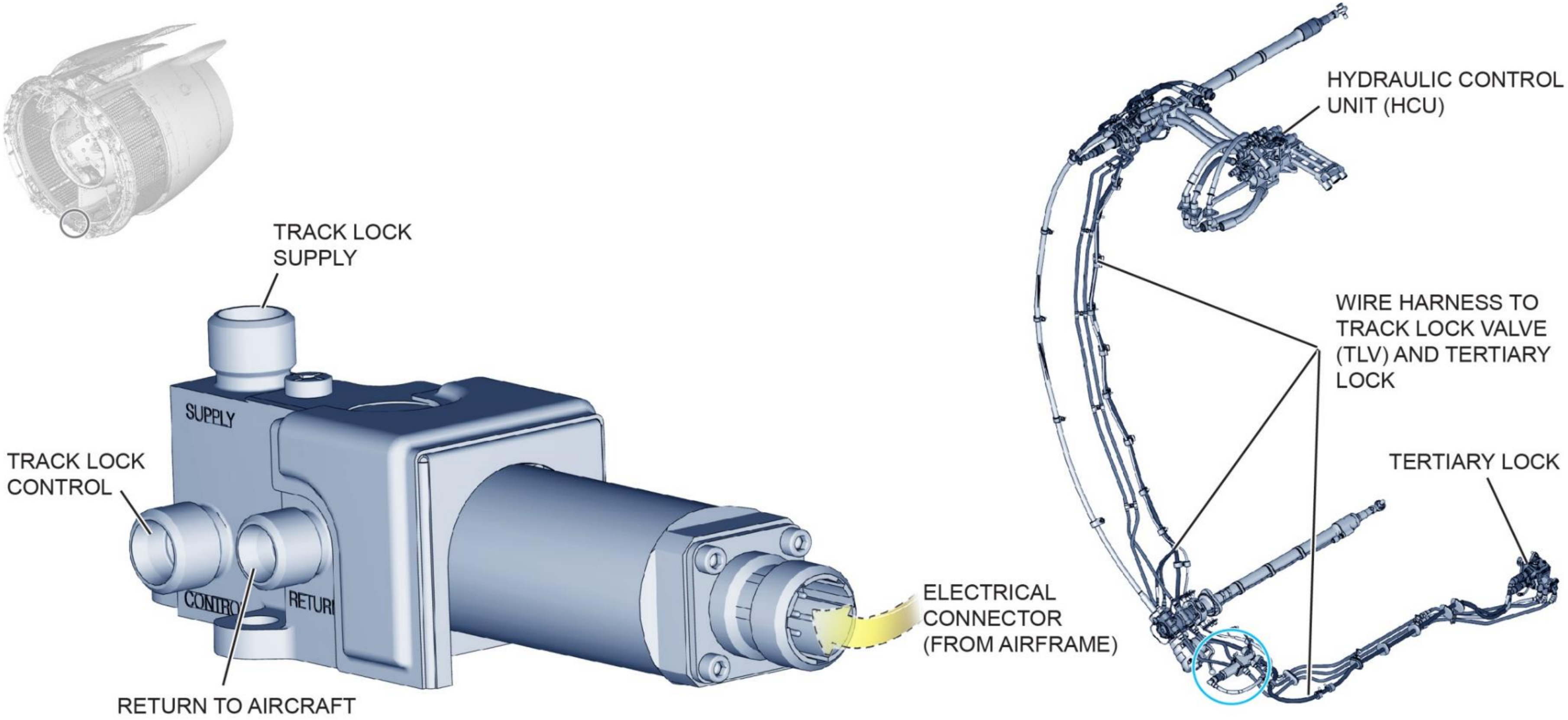
Description

The TLV is independently controlled by a 115 VAC aircraft signal, which is external to the TRAS and provides fully independent control of the tertiary locks.

The TLV is considered part of the “third line of defence” to prevent inadvertent deployment of the thrust reverser during flight.

Operation:

When energized, the TLV solenoid allows fluid to be ported to the tertiary locks, unlocking them for deployment of the thrust reverser.


TRACK LOCK
SUPPLY
SUPPLY
TRACK LOCK
CONTROL
CONTRO
RETUR
RETURN TO AIRCRAFT
ELECTRICAL
CONNECTOR
(FROM AIRFRAME)
HYDRAULIC CONTROL
UNIT (HCU)
WIRE HARNESS TO
TRACK LOCK VALVE
(TLV) AND TERTIARY
LOCK
TERTIARY LOCK

Thrust Reverser Actuation System (TRAS) (Cont.)

Tertiary Lock

Purpose:

If the mechanical locking system fails to retain translating sleeves, the tertiary lock prevents the transcowl from deploying past the stowed position.

Location:

The Tertiary Lock is mounted to the aft section of the latch beam.

Description:

Each Tertiary Lock incorporates two proximity switches which provide lock/unlock status to the EEC.

The Tertiary Lock is biased to the locked position by four springs between the blade and the piston.

Operation:

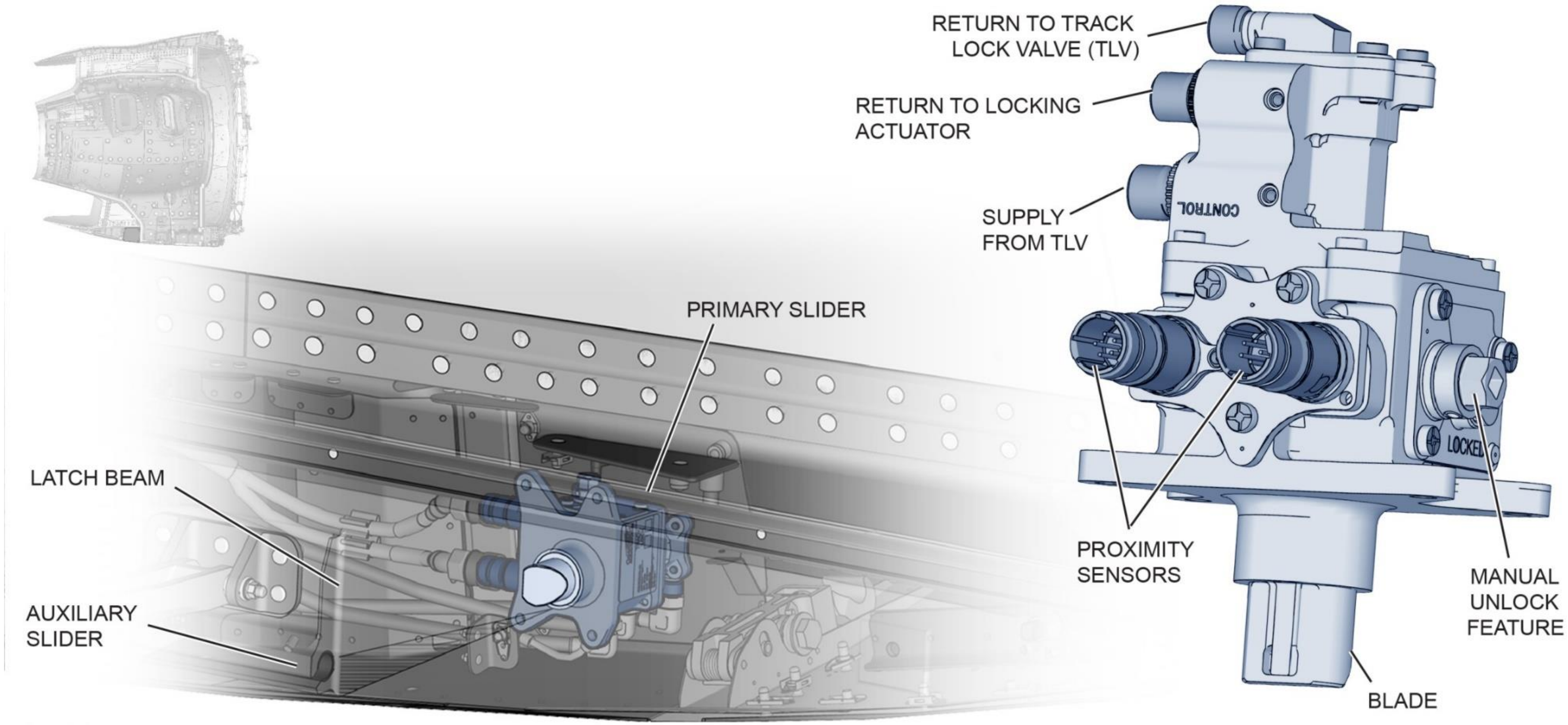
1. Once the Track Lock Valve is commanded open by the aircraft, the TLV solenoid energizes, and the blade on the Tertiary Lock translates to the unlocked position.

2. Proximity sensor targets move to the “far” position, allowing them to send redundant signals to the aircraft that indicate the tertiary lock is unlocked.

3. The thrust reverser deploys.

4. When the Tertiary Locks receive supply pressure ported from the energized TLV, the piston retracts the blade, allowing the Tertiary Lock to unlock.

5. Once the transcowl has translated outside of the stowed locking region, the solenoid stays energized, allowing the Tertiary Lock to remain unlocked until the TRAS is returned to the stowed position.



NOTE:
LEFT THRUST REVERSER DOOR COMPONENTS SHOWN. RIGHT DOOR IS IDENTICAL

Door Opening System (DOS)

Purpose:

The Door Opening System (also known as the thrust reverser opening mechanism) opens the thrust reverser cowl assembly and provides maintenance access to the engine core.

Location:

The DOS is located in the fan compartment.

Actuators are attached to the engine fan case on one end, and the thrust reverser torque box on the other end.

Description:

The system consists of an electro-hydraulic power pack, a reservoir, two reverser cowl C-duct actuators, and two operating switches.

Power for the system comes from the aircraft.

A manually operated hydraulic pump is coupled to the actuator.

When the hydraulic fluid is pressurized, the pressure within the actuator holds the thrust reverser in the open position so a Hold Open Rod can be connected.

Operation:

The C-duct configuration provides maintenance and service access to the engine when the halves are opened by the DOS.

This is actuated via command switches located on the fan compartment.

Hold Open Rods are provided to allow one opening angle of approximately 45°.

Operating switches mounted on the left and right hand sides of the fan case allow for easy opening of the C-ducts.

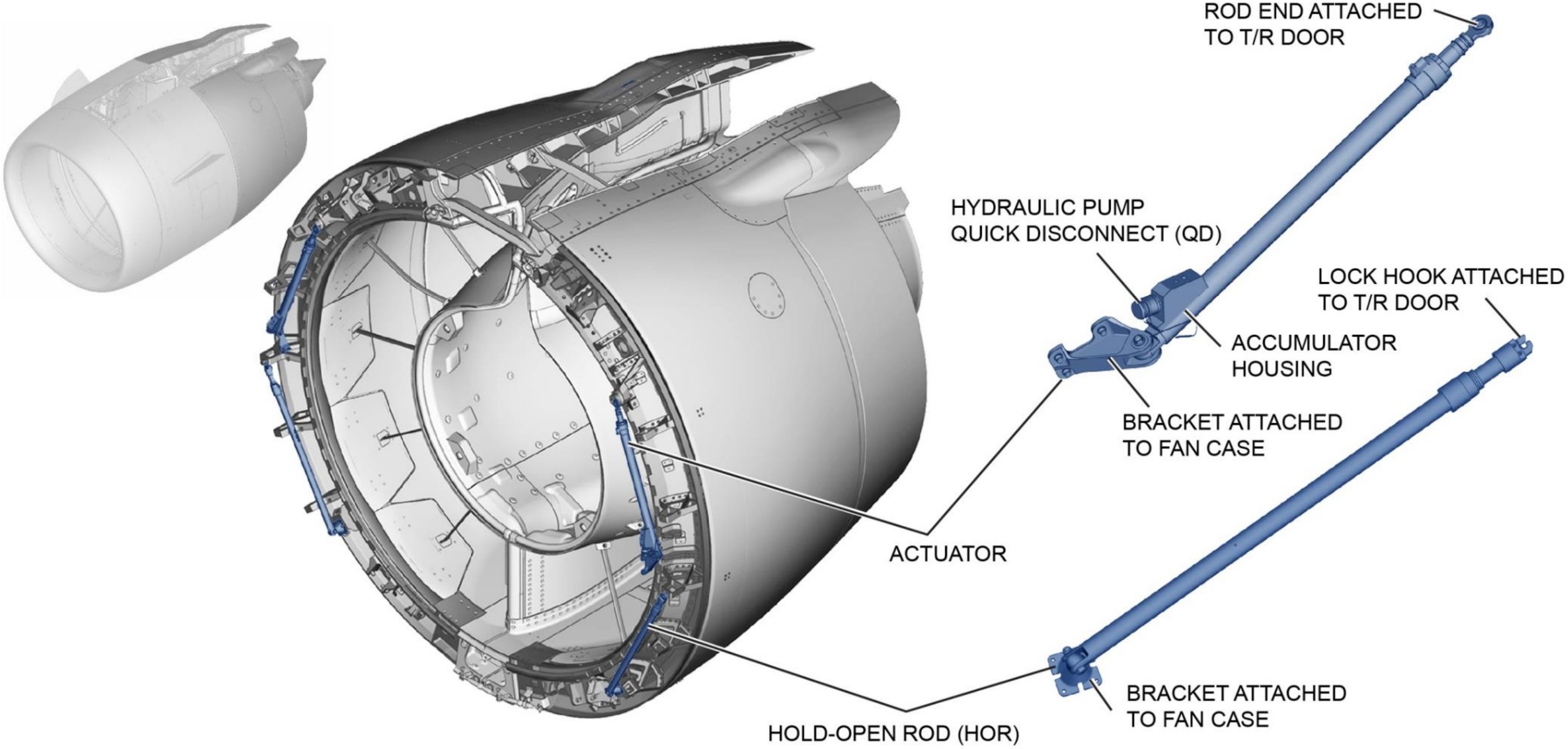
Pressing and holding the switch activates the hydro-electric power pack.

The pack pressurizes the oil stored in the reservoir and supplied to the left or right actuator, depending on the switch being used.

The actuator will lift the door and lock once the door is in its proper opening position.

Once in position, Hold Open Rods can be installed to keep the doors safely open for maintenance.

In the event power is not available, a quick-disconnect fitting on the actuators allows the doors to be opened manually with a single action hand pump.


ROD END ATTACHED
TO T/R DOOR
HYDRAULIC PUMP
QUICK DISCONNECT (QD)
LOCK HOOK ATTACHED
TO T/R DOOR
ACCUMULATOR
HOUSING
BRACKET ATTACHED
TO FAN CASE
ACTUATOR
BRACKET ATTACHED
TO FAN CASE
HOLD-OPEN ROD (HOR)

TURBINE EXHAUST SYSTEM

The Turbine Exhaust System is a cylindrical barrel and cone that makes a smooth exit for fan air and engine exhaust during engine operation.

The system helps mix the fan bypass air with the turbine exhaust air. It reduces exhaust noise and helps increase thrust and performance.

The system is installed on the aft flange of the engine.

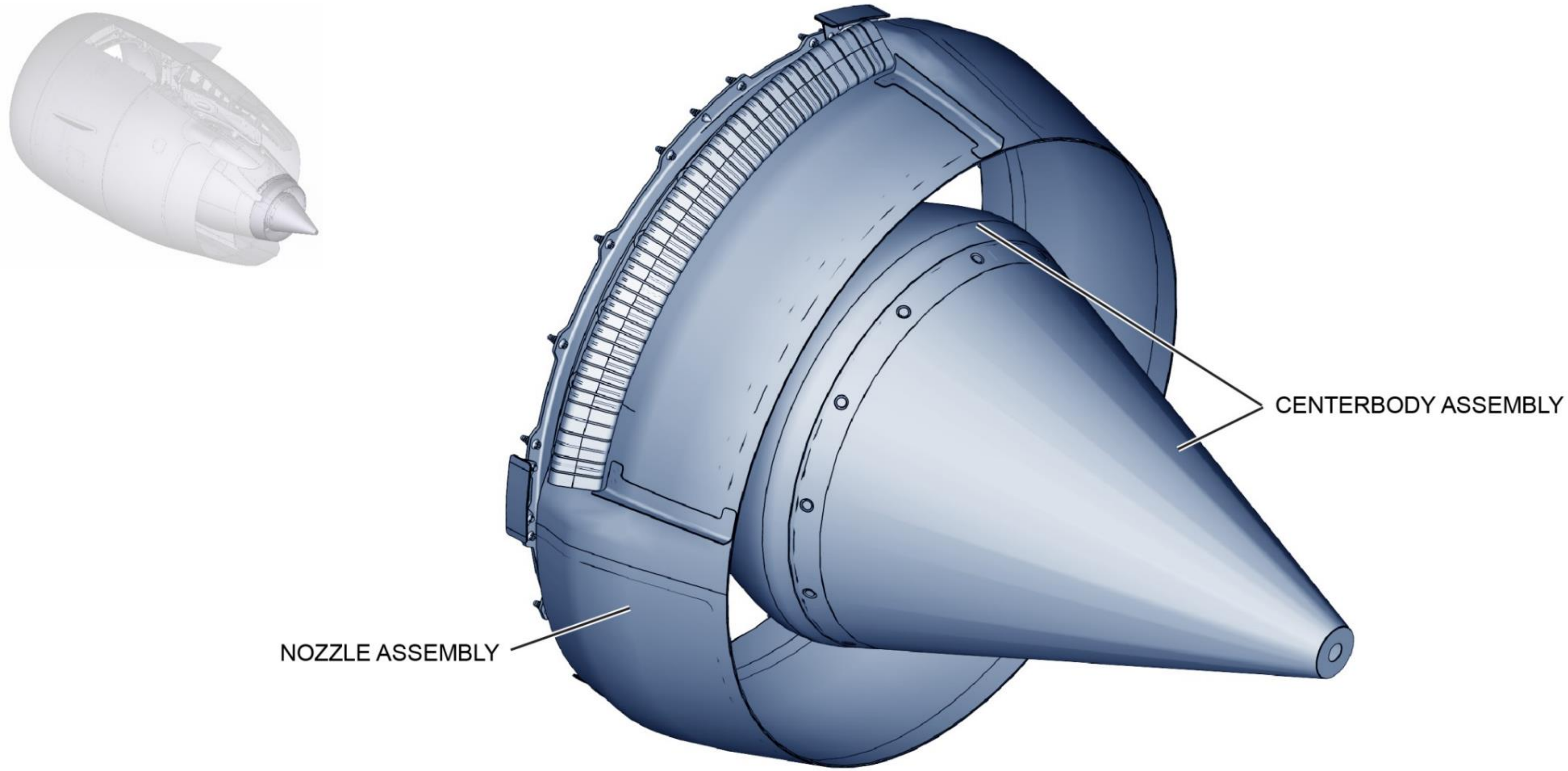
Major components include centre body and nozzle assemblies.

The two assemblies help to control the engine exhaust gas flow and send the gas aft.

They also supply an aerodynamically smooth surface for the fan air from the thrust reverser.

The system also incorporates drainage provisions to expel any hazardous fluids or vapours.

Drainage outlets are found at the nozzle assembly, and at forward and aft centre bodies at 6:00.


CENTERBODY ASSEMBLY
NOZZLE ASSEMBLY

Turbine Exhaust Centre body Assembly (Exhaust Plug)

Purpose:

The centre body assembly helps to control the engine exhaust gas flow and helps the nozzle to send gas aft.

Location:

The assembly is attached to the rear of the Turbine Exhaust Case.

Description:

The centre body assembly provides an aerodynamic smooth surface for exhaust airflow and is designed to accelerate exhaust flow to high speeds.

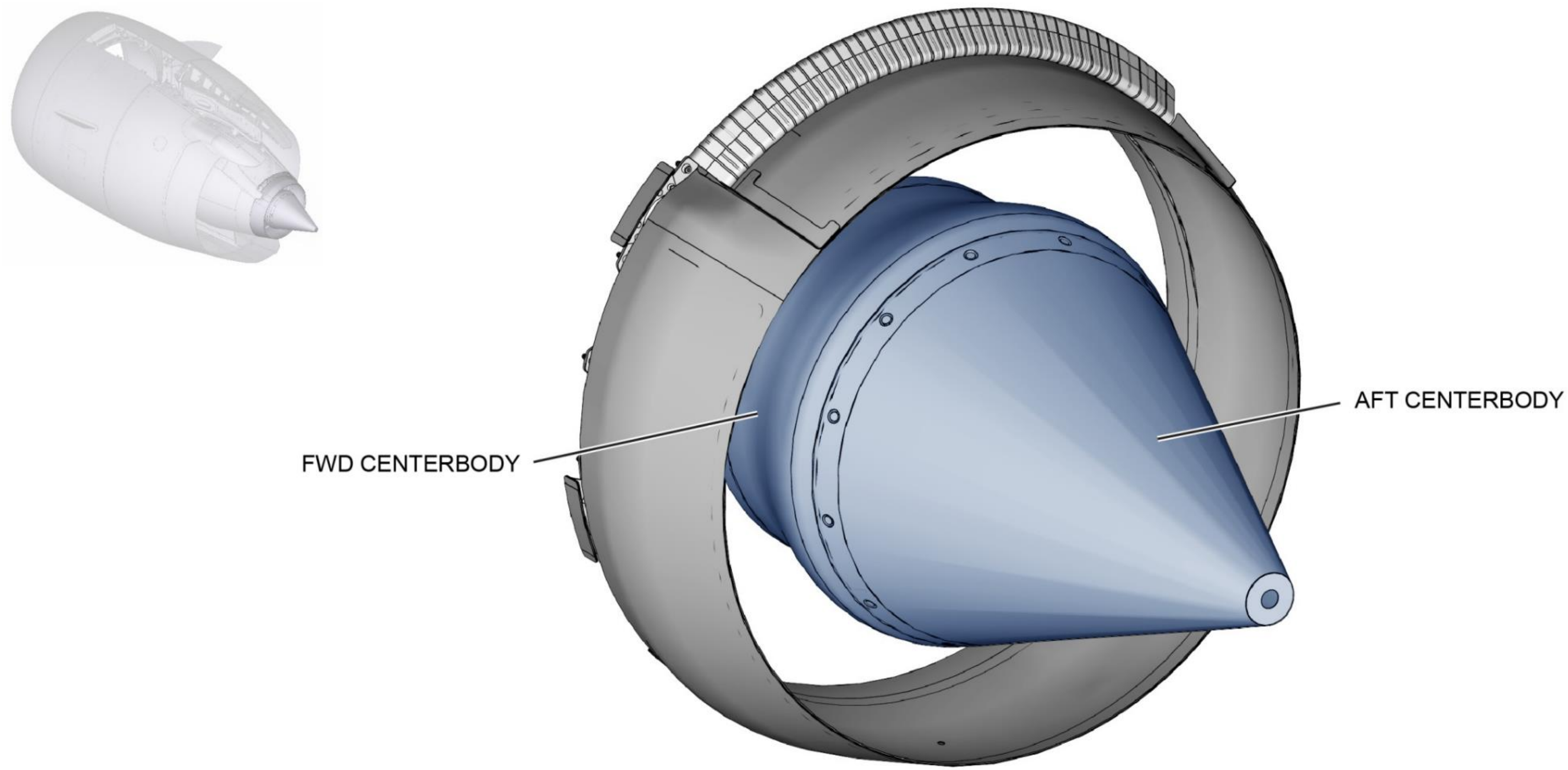
The assembly has both forward and aft sections.

The forward Centre body assembly is installed with 23 bolts on the *Ti* flange of the engine's TEC.

The aft centre body assembly is attached to the forward centre body assembly with 13 bolts and nut plates.

The forward centre body drain is at 6:00.

Two alignment pins at 12:00 and 5:00 on the forward centre body flange facilitate proper clocking of the centre body drain provisions.


FWD CENTERBODY
AFT CENTERBODY

Turbine Exhaust Nozzle Assembly

Purpose:

The Turbine Exhaust Nozzle Assembly provides an efficient exit path for the engine exhaust gases leaving the LPT at a velocity and direction required to produce forward thrust.

Location:

The exhaust nozzle assembly is a tapering cylindrical barrel installed on the *To* flange of the Turbine Exhaust Case.

The nozzle assembly drain is at 6:00.

Description:

The exhaust nozzle assembly consists of these components:

- nozzle
- fire seal fingers (“turkey feathers”)
- cross flow blockers.

The forward outer surface of the assembly aligns with the thrust reverser inner duct surface.

The inner surface makes the outer contour of the engine exhaust.

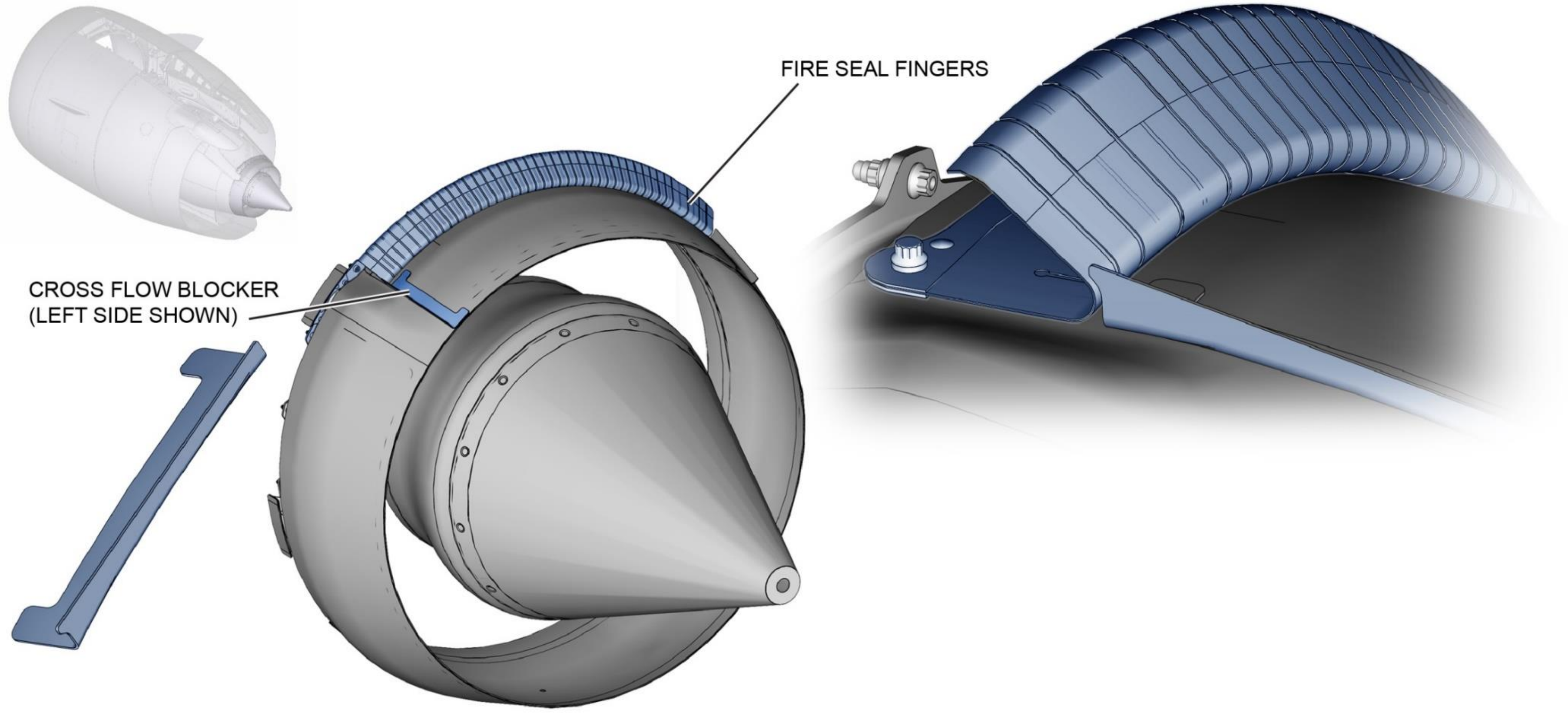
Fire seal fingers, or “turkey feathers” at the top of the exhaust nozzle prevent flames from exiting or entering the core compartment area in the unlikely event of a fire.

Two cross flow blockers, one on each side of the Aft Pylon Fairing (APF), reduce the amount of hot core compartment air entering the fairing.

The top of the exhaust nozzle has a pylon fire seal.

Diverters to the left and right of the pylon seal help prevent cross flow of the exhaust under the pylon aft fairing.

The nozzle is not in a flammable fluid zone.


FIRE SEAL FINGERS
CROSS FLOW BLOCKER
(LEFT SIDE SHOWN)

Turbine Exhaust Nozzle Assembly

Description (Cont.):

Eight outer fairing pads on the side provide protection to the exhaust nozzle during the translating sleeve operation.

The exhaust nozzle assembly is made of Inconel alloys.

The attachment flange has alignment pin holes at 12:00 and 6:00 to position the drain provisions.

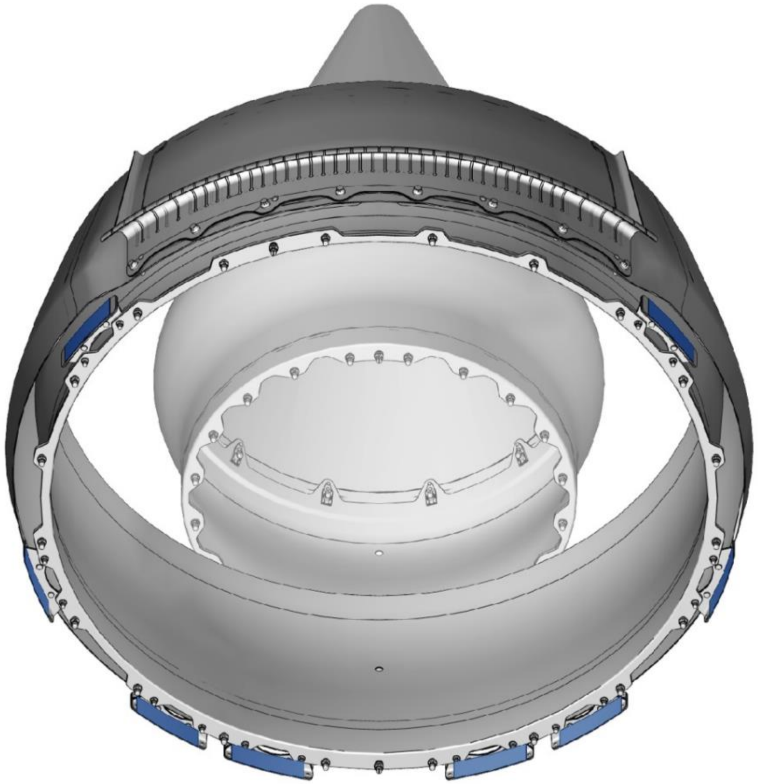
Note: the exhaust nozzle can be removed with the engine lift bracket installed. Scallops have been designed to clear the lift bracket nuts.

A snubber bracket assembly limits deflections of the thrust reverser during flight.

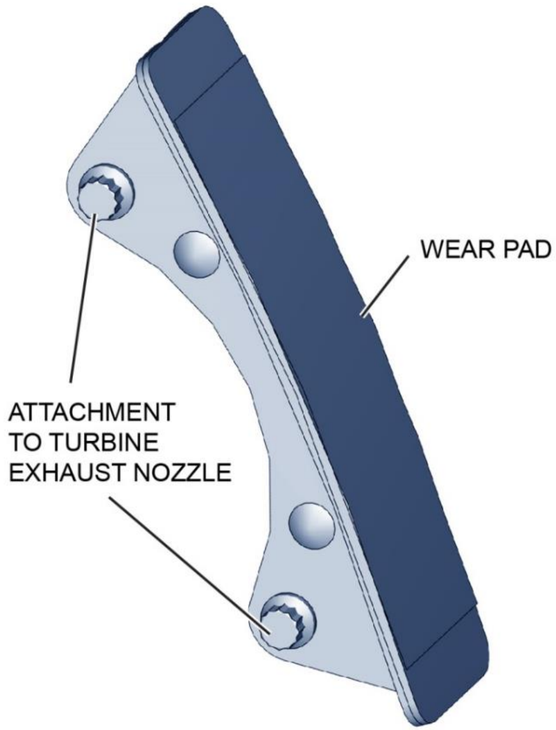
The assembly interfaces between the nozzle assembly and the thrust reverser, and includes a coated wear pad to prevent premature wear of the snubber bracket.

A total of eight snubber bracket assemblies are located on the nozzle assembly, four to each side.

The wear pads are attached to the snubber bracket assembly with four countersunk rivets.



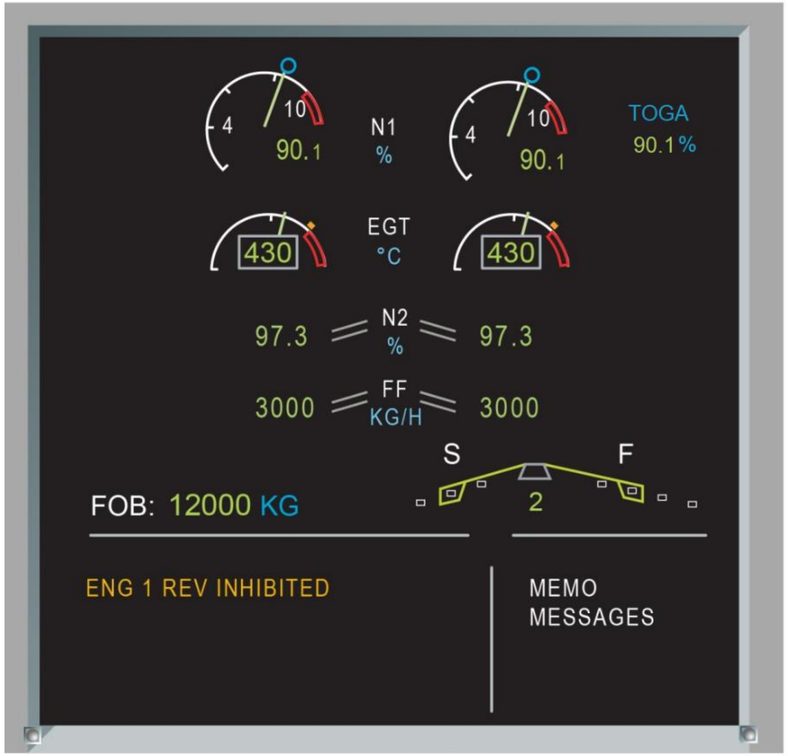
TURBINE EXHAUST NOZZLE



SNUBBER BRACKET ASSEMBLY

INTENTIONALLY BLANK

FLIGHT CREW INITIAL WARNING



ENGINE/WARNING DISPLAY

INTERACTIVE MODE FOR MAINTENANCE ACTION

MULTIPURPOSE CENTRALIZED DISPLAY UNIT (MCDU)

SAMPLE ECAM MESSAGES FOR ATA 78

THRUST REVERSER SYSTEM LAYOUT

The thrust reverser system is of the aerodynamic blockage type.

For each engine, it consists of two translating sleeves, ten blocker doors and cascade vanes to redirect fan discharge airflow.

Each system is pressurized by its dedicated hydraulic power source:

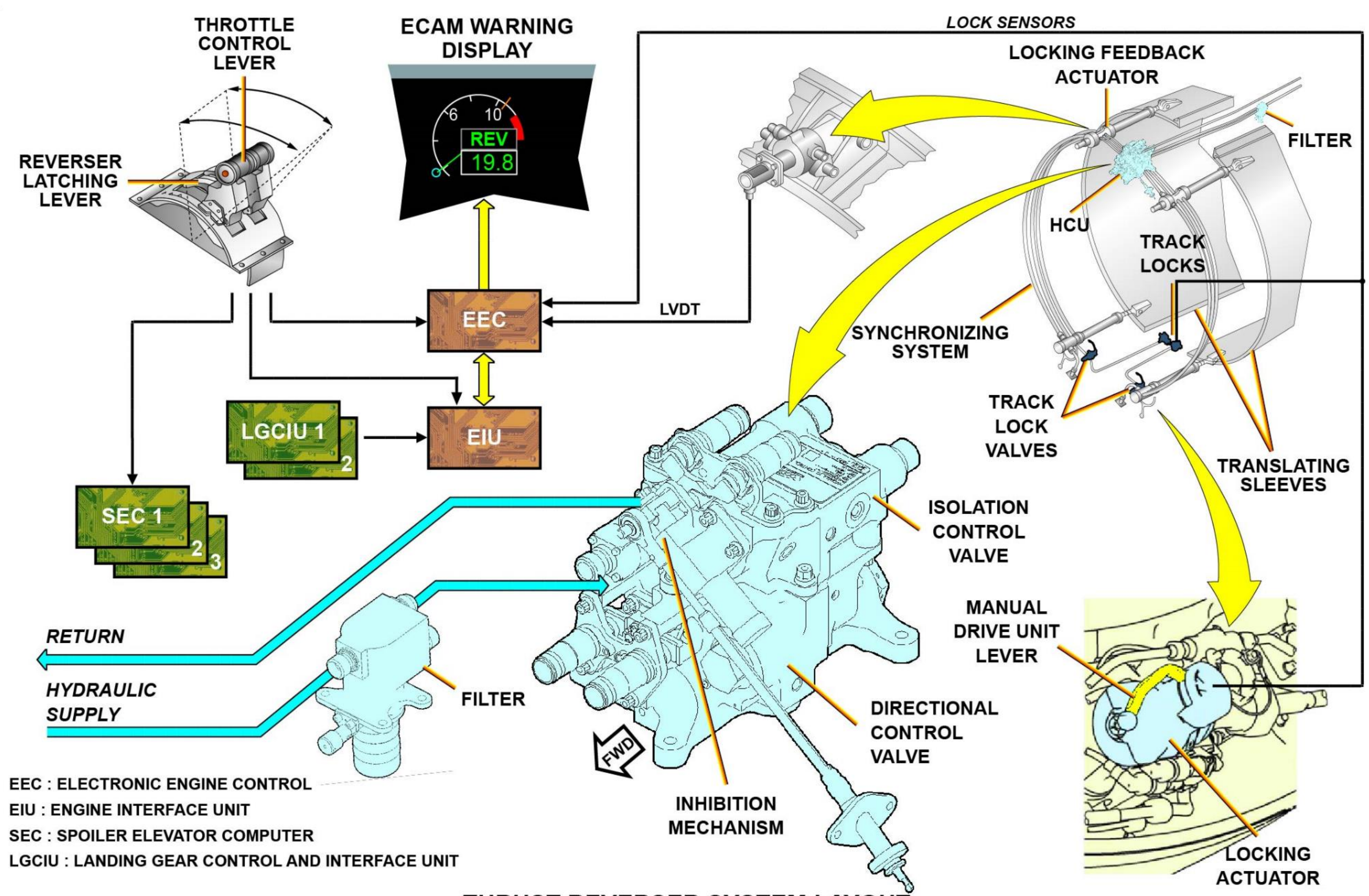
Green hydraulic pressure for engine 1,

Yellow one for engine 2.

Each system is made of one Hydraulic Control Unit (HCU) including an Isolation Control Valve (ICV) and a Directional Control Valve (DCV), two worm drive actuators per side, locking and monitoring devices.

To avoid inadvertent deployment, the system operates under multiple and independent commands and it comprises several lines of defence:

primary locks in each actuator and one tertiary lock at the bottom of each translating sleeve.



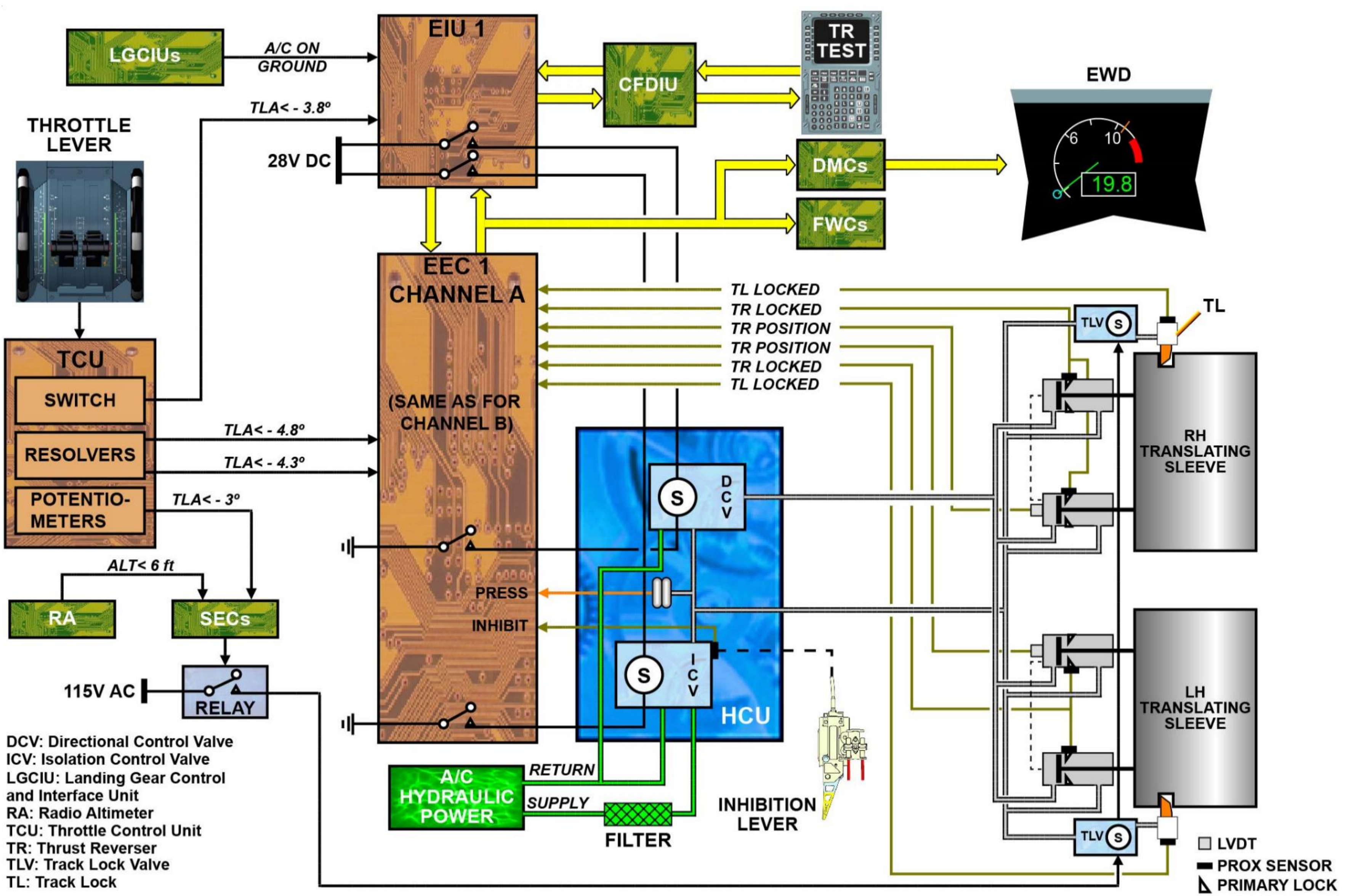
THRUST REVERSER SYSTEM LAYOUT

DEPLOY SEQUENCE

The EEC confirms the engine is running. The thrust reversers are stowed, locked and not inhibited.

In these conditions:

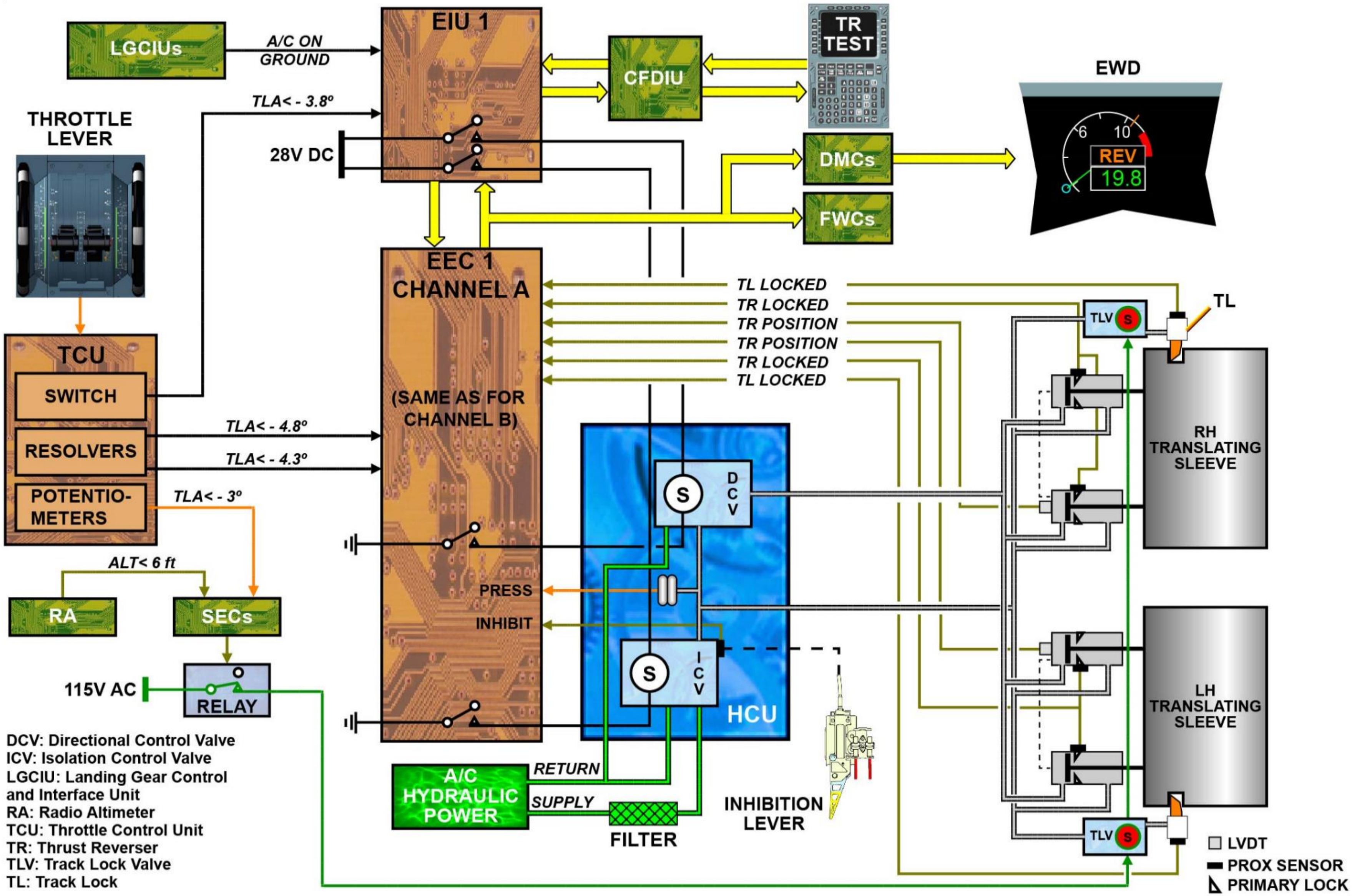
- the ICV, DCV, Track Lock Valves (TLV) are de-energized to prevent pressurization,
- the 6 proximity sensors indicate locked,
- the ICV pressure switch indicates a low pressure,
- both LVDTs indicate a stowed condition,
- the HCU inhibition lever proximity sensor indicates a non-inhibited condition.


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
6
10
19.8
DMCs
FWCs
THROTTLE LEVER
TLA< - 3.8º
28V DC
EEC 1 CHANNEL A
(SAME AS FOR CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
TLA< - 4.8º
TLA< - 4.3º
TLA< - 3º
RH TRANSLATING SLEEVE
LH TRANSLATING SLEEVE
DCV
ICV
HCU
PRESS
INHIBIT
ALT< 6 ft
RA
SECs
115V AC
RELAY
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
LVDT
PROX SENSOR
PRIMARY LOCK
DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

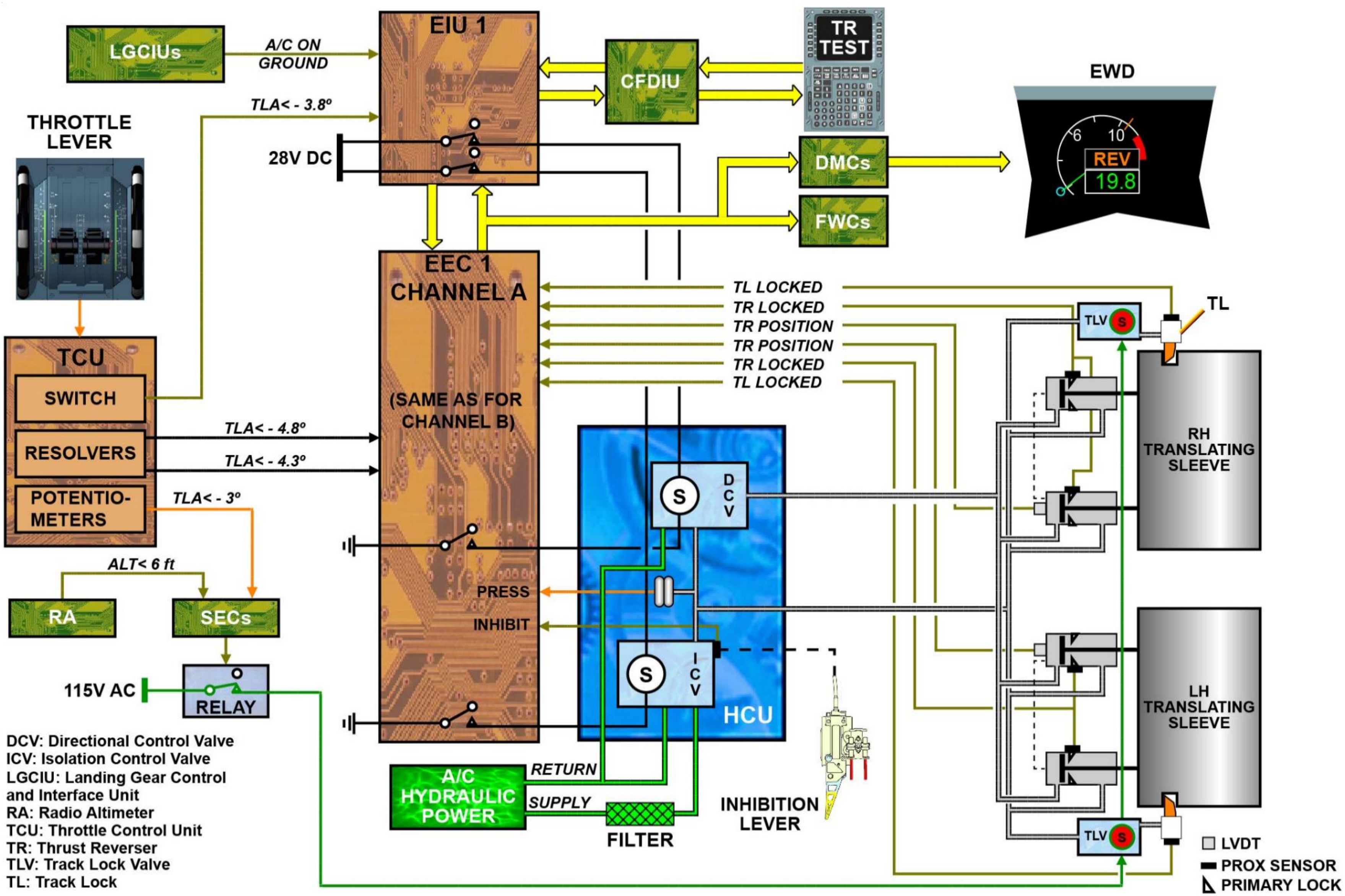
When the thrust-reverser lever is set to the deploy position, the following sequence occurs.

1 - As soon as the Spoiler Elevator Computers (SECs) receive the signal from the TCU potentiometers (Throttle Lever Angle (TLA) < -3°), and from the Radio Altimeter (RA) (altitude < 6 ft.), they control the powering of the TLVs to open.

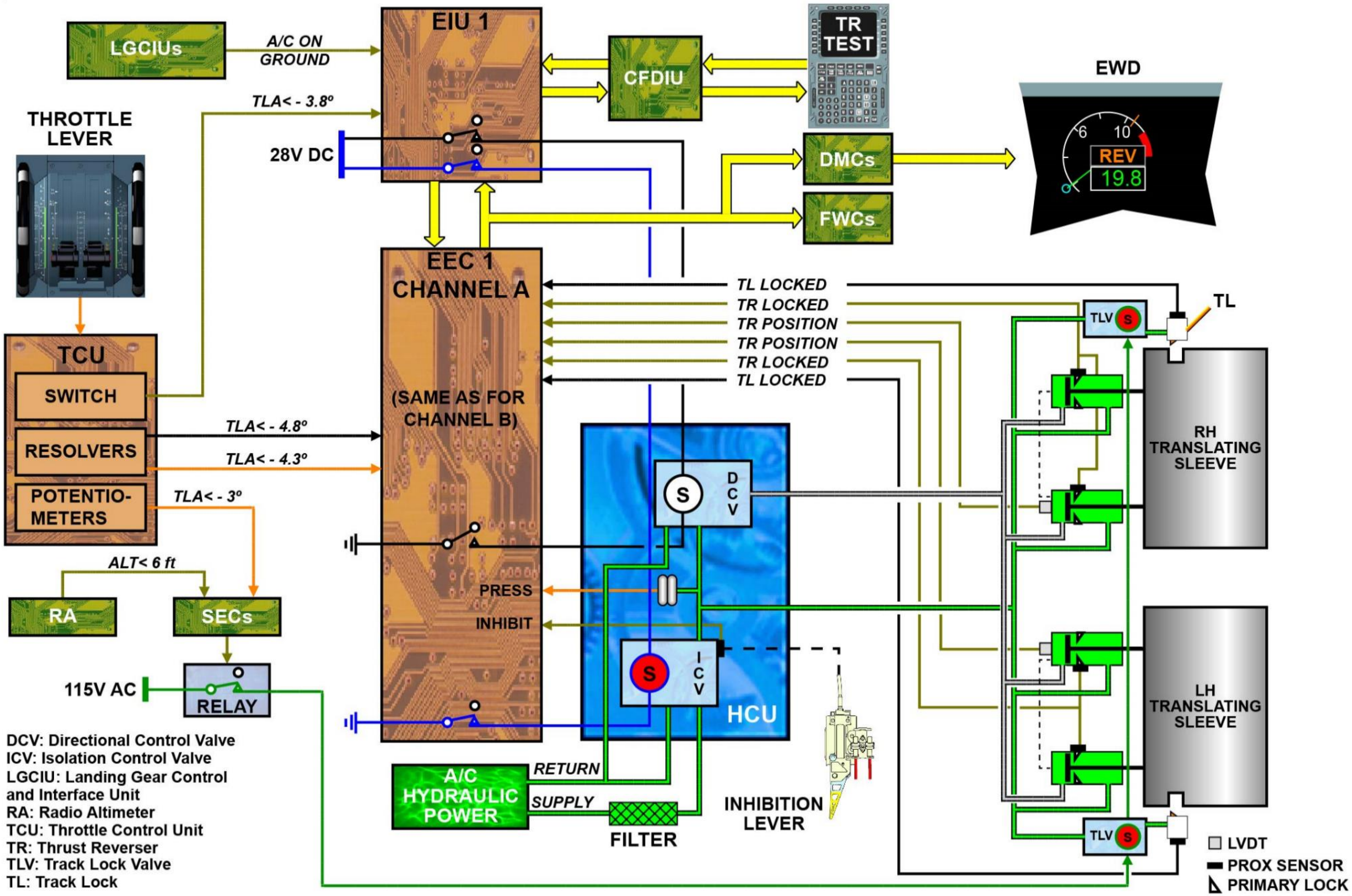
In this position, the TLVs are ready to let the hydraulic pressure release the Track Lock (TL) when the ICV will be controlled open.


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
REV
19.8
TLA< - 3.8°
THROTTLE LEVER
28V DC
DMCs
FWCs
EEC 1 CHANNEL A
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
(SAME AS FOR CHANNEL B)
TLA< - 4.8°
TLA< - 4.3°
TLA< - 3°
RH TRANSLATING SLEEVE
D C V
ICV
ALT< 6 ft
RA
SECs
PRESS
INHIBIT
115V AC
RELAY
HCU
LH TRANSLATING SLEEVE
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
LVDT
PROX SENSOR
PRIMARY LOCK
DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

2 - When the Engine Interface Unit (EIU) receives the signals from the Throttle Control Unit (TCU) switch (TLA < -3.8°) and from the Landing Gear Control and Interface Units (LGCIUs) (aircraft on ground), it controls the closure of internal relays involved in the ICV and DCV powering.


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
REV
19.8
6
10
TLA< - 3.8º
THROTTLE LEVER
28V DC
DMCs
FWCs
EEC 1 CHANNEL A
(SAME AS FOR CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
TLA< - 4.8º
TLA< - 4.3º
TLA< - 3º
D C V
S
RH TRANSLATING SLEEVE
LH TRANSLATING SLEEVE
ALT< 6 ft
RA
SECs
PRESS
INHIBIT
I C V
HCU
115V AC
RELAY
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock
LVDT
PROX SENSOR
PRIMARY LOCK

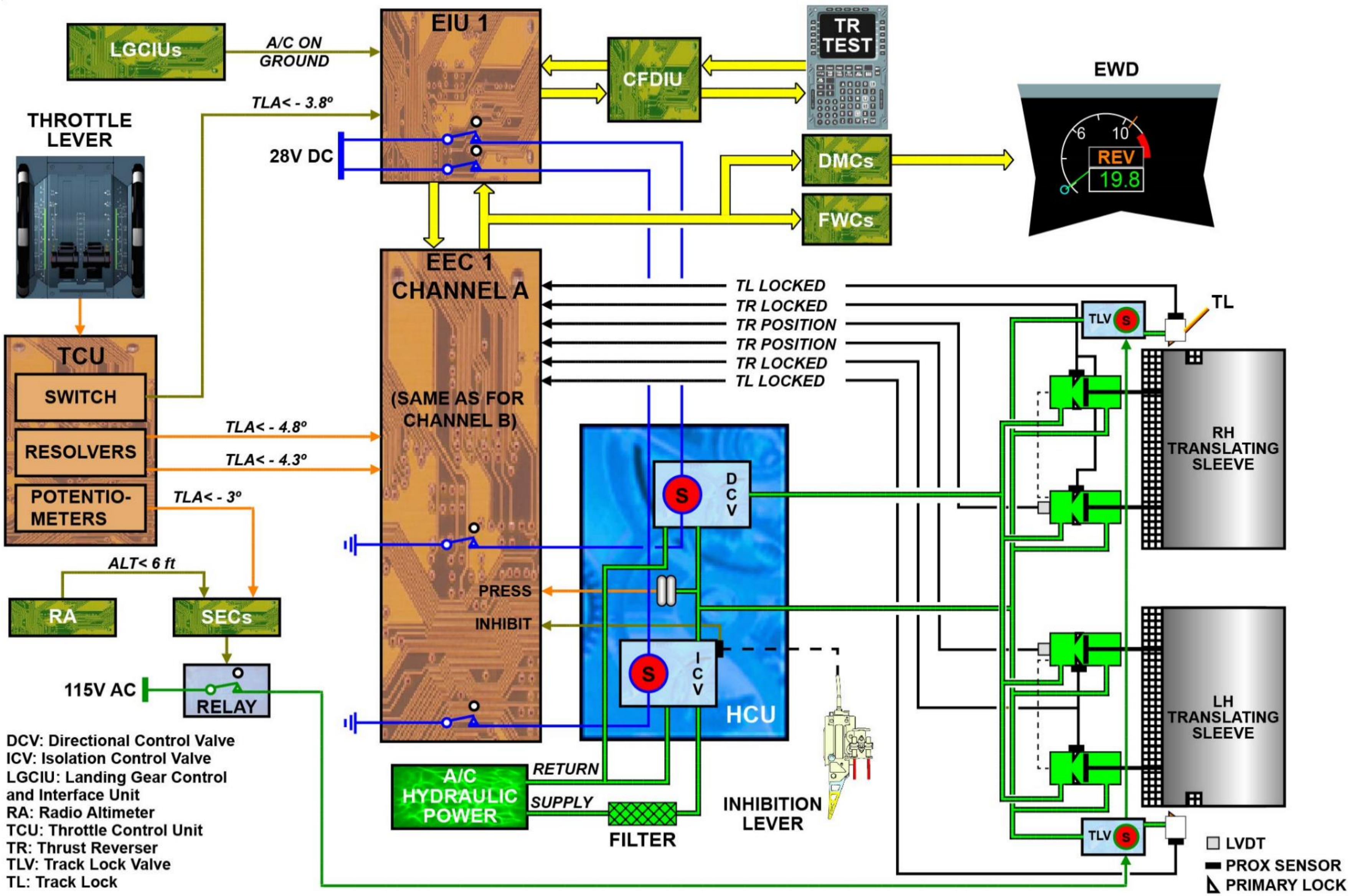
3 - When the Electronic Engine Control (EEC) receives the signals from the TCU resolvers (TLA < -4.3°), it closes an internal relay to power the ICV to open. The pressure is sent to the actuators rod chambers to perform an overstow and to the TLs to release the latches.



DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

4 - When the EEC receives the signals from the TCU resolvers (TLA < -4.8°) provided the TLs are confirmed unlocked, it closes an internal relay to power the DCV to open.

The pressure is sent to the actuators jack heads to release the actuators internal primary locks and command the translating sleeves deployment.

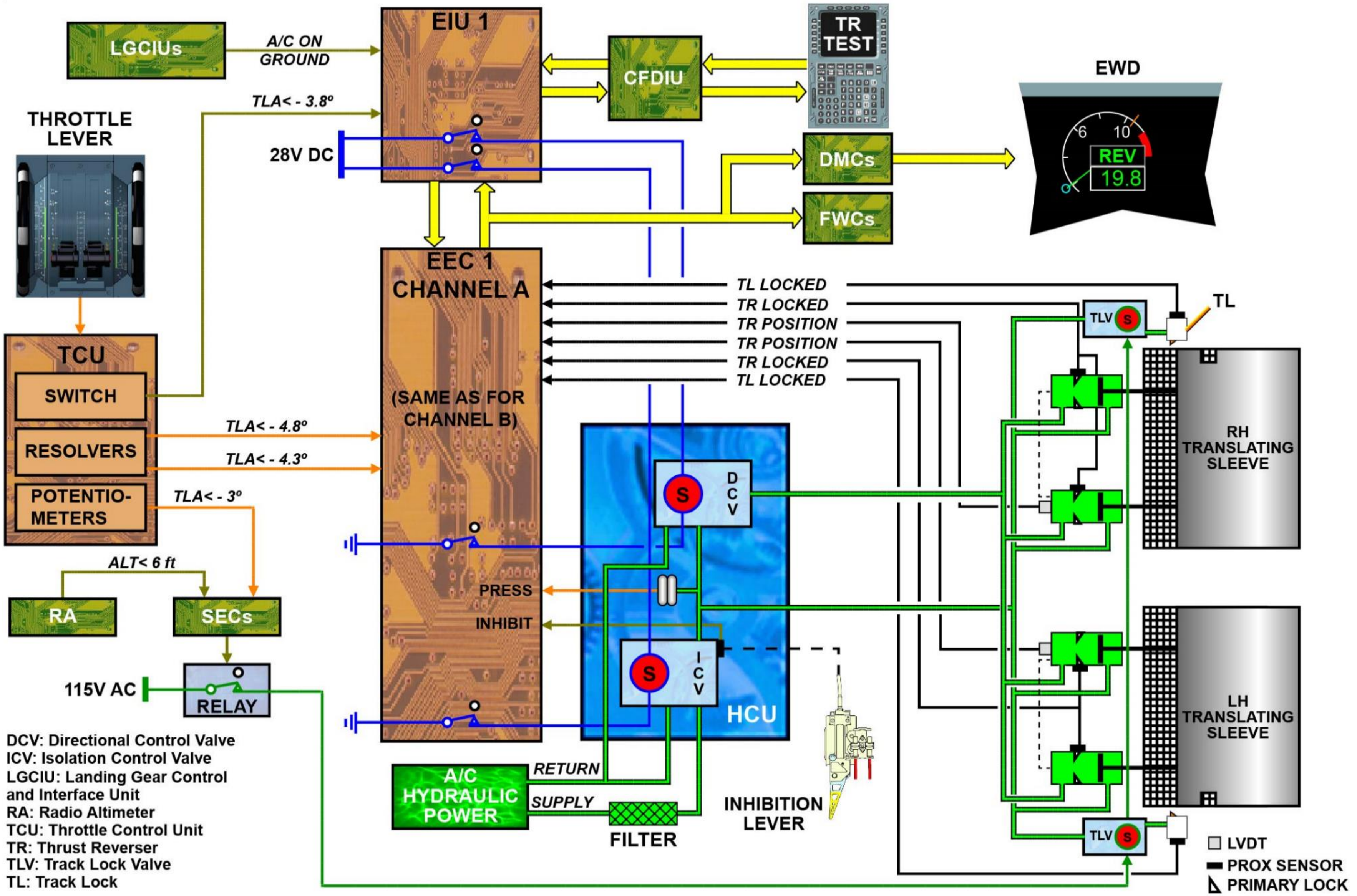


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
6
10
REV
19.8
DMCs
FWCs
THROTTLE LEVER
TLA< - 3.8º
28V DC
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
TLA< - 4.8º
TLA< - 4.3º
TLA< - 3º
EEC 1 CHANNEL A
(SAME AS FOR CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
RH TRANSLATING SLEEVE
LH TRANSLATING SLEEVE
D C V
I C V
HCU
PRESS
INHIBIT
ALT< 6 ft
RA
SECs
115V AC
RELAY
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
LVDT
PROX SENSOR
PRIMARY LOCK
DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

5 - Above 85 % of travel, the EEC commands the engine to accelerate from reverse idle to max reverse thrust. Maximum allowable thrust is defined as a function of sleeve travel and TLA.

At 95% of travel, the actuators engage their integral snubbing devices, thus decreasing their extension speed before the full opening.

The TLV, ICV and DCV remain supplied to maintain the translating sleeves fully deployed by hydraulic pressure.


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
TLA< - 3.8°
THROTTLE LEVER
28V DC
DMCs
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REV
19.8
EEC 1 CHANNEL A
(SAME AS FOR CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
TLA< - 4.8°
TLA< - 4.3°
TLA< - 3°
D C V
RH TRANSLATING SLEEVE
ALT< 6 ft
RA
SECs
PRESS
INHIBIT
115V AC
RELAY
I C V
HCU
LH TRANSLATING SLEEVE
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
LVDT
PROX SENSOR
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DCV: Directional Control Valve
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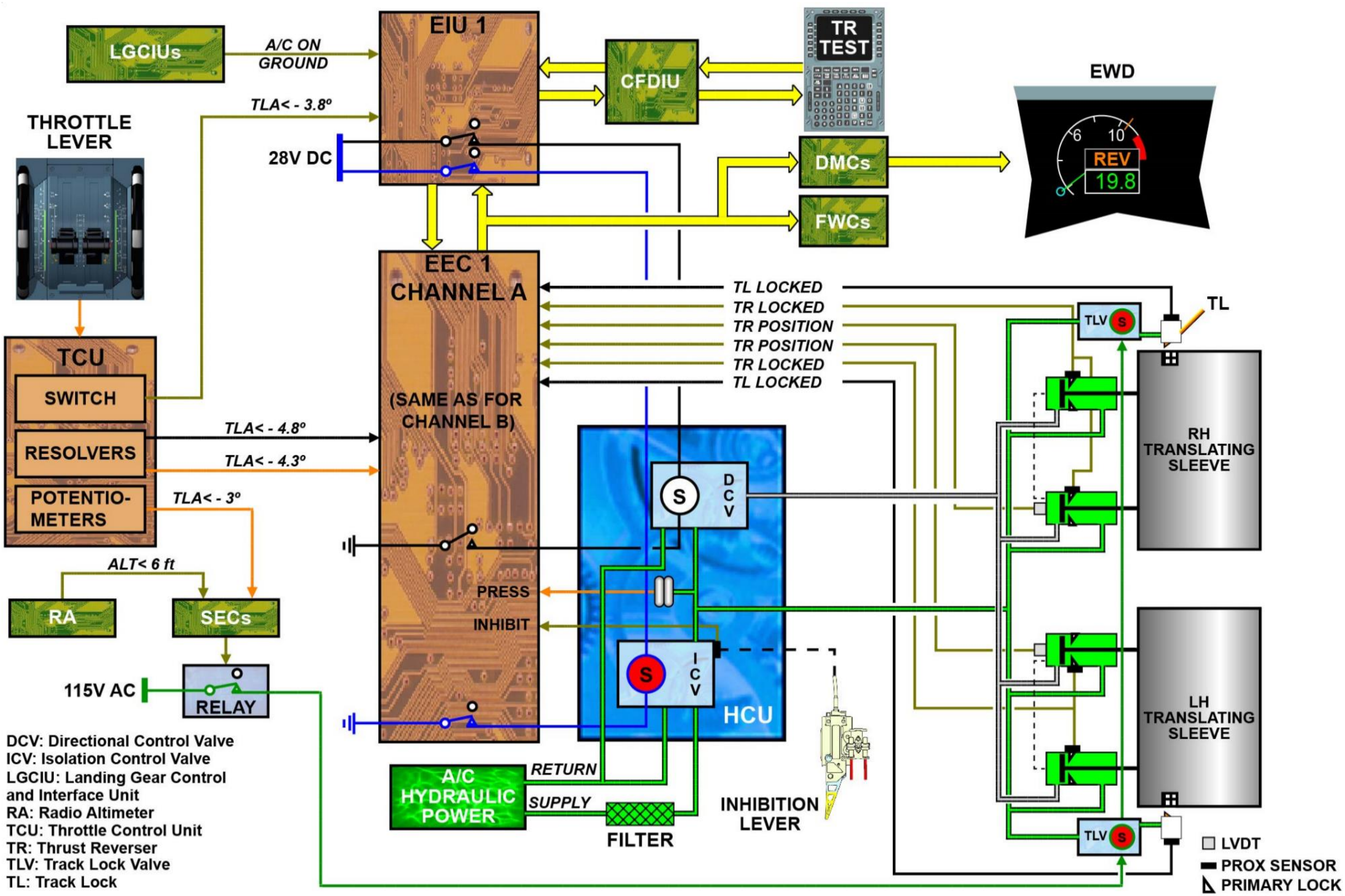
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

STOW SEQUENCE

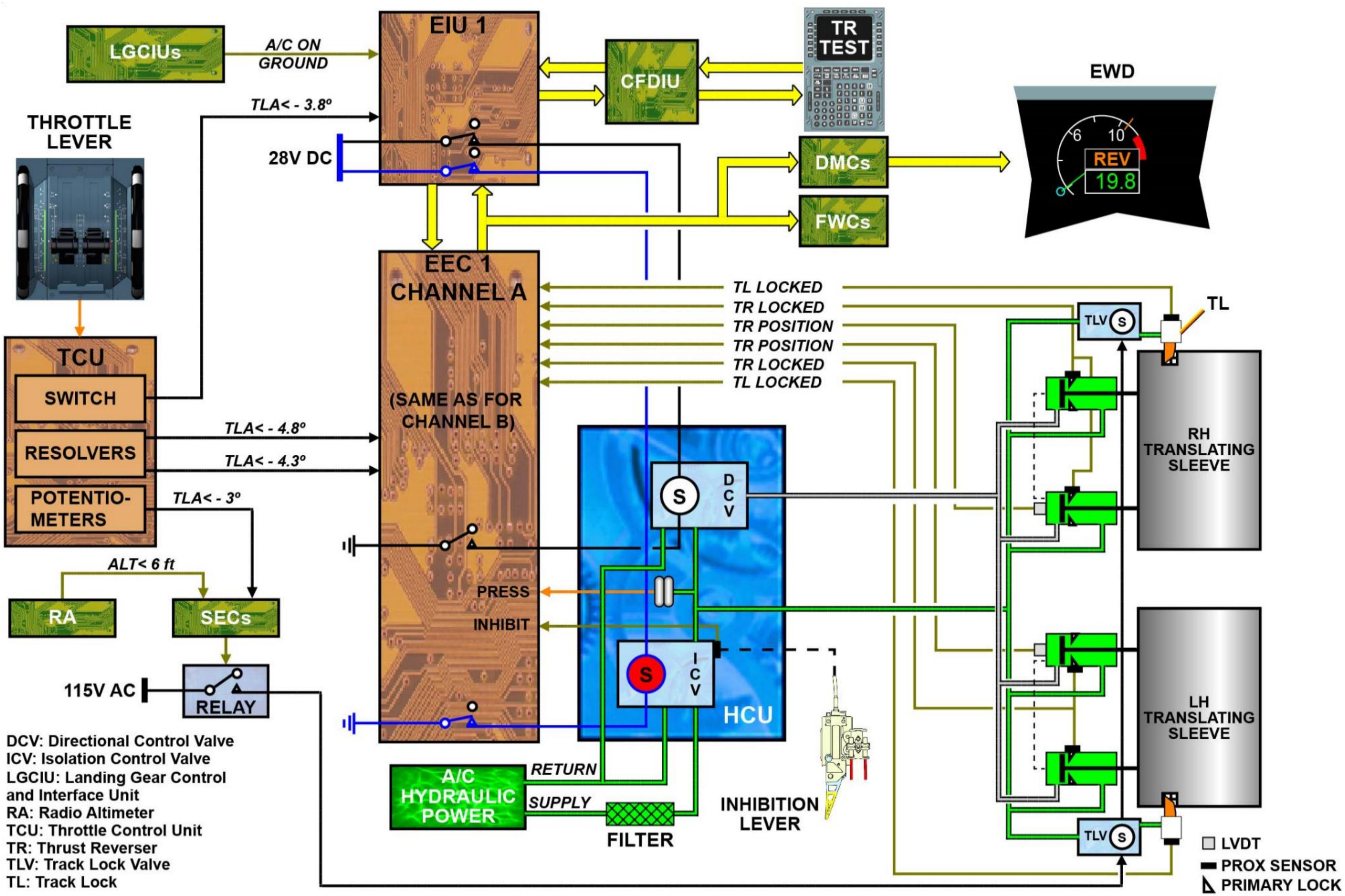
When the thrust-reverser lever is set to the stow position, the following sequence occurs.

1 - When the EEC receives the signals from the TCU resolvers (TLA > -4.8°), it de-energizes the DCV.

The pressure is sent only to the actuators rod chambers to stow the translating sleeves until the actuators internal primary locks are re-engaged.


LGCIUs
A/C ON GROUND
EIU 1
CFDIU
TR TEST
EWD
REV
19.8
THROTTLE LEVER
TLA< - 3.8º
28V DC
DMCs
FWCs
EEC 1 CHANNEL A
(SAME AS FOR CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
TCU
SWITCH
RESOLVERS
POTENTIO-METERS
TLA< - 4.8º
TLA< - 4.3º
TLA< - 3º
RH TRANSLATING SLEEVE
D C V
HCU
ALT< 6 ft
RA
SECs
PRESS
INHIBIT
I C V
115V AC
RELAY
LH TRANSLATING SLEEVE
A/C HYDRAULIC POWER
RETURN
SUPPLY
FILTER
INHIBITION LEVER
LVDT
PROX SENSOR
PRIMARY LOCK
DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock

2 - 15 seconds after the SECs receive the signals from the TCU potentiometers (TLA > -2°), they de-energize the TLVs to re-engage the TLs.


LGCIUs
A/C ON
GROUND
EIU 1
CFDIU
TR
TEST
EWD
REV
19.8
THROTTLE
LEVER
TLA< - 3.8º
28V DC
DMCs
FWCs
EEC 1
CHANNEL A
(SAME AS FOR
CHANNEL B)
TL LOCKED
TR LOCKED
TR POSITION
TR POSITION
TR LOCKED
TL LOCKED
TL
TLV
S
TCU
SWITCH
RESOLVERS
POTENTIO-
METERS
TLA< - 4.8º
TLA< - 4.3º
TLA< - 3º
RH
TRANSLATING
SLEEVE
D
C
V
ALT< 6 ft
RA
SECs
PRESS
INHIBIT
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C
V
HCU
LH
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115V AC
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DCV: Directional Control Valve
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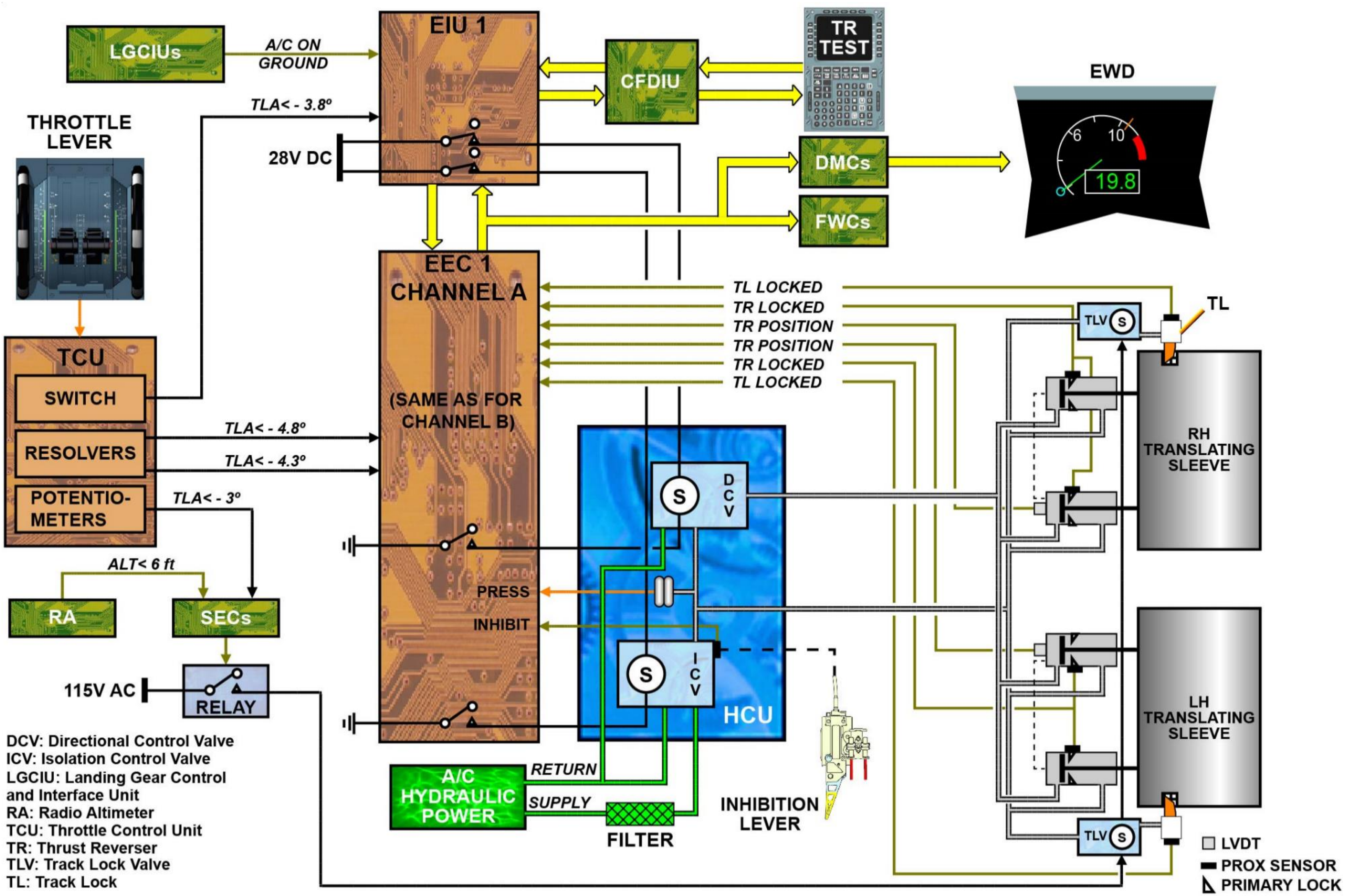
RA: Radio Altimeter
TCU: Throttle Control Unit
TR: Thrust Reverser
TLV: Track Lock Valve
TL: Track Lock
A/C
HYDRAULIC
POWER
RETURN
SUPPLY
FILTER
INHIBITION
LEVER
LVDT
PROX SENSOR
PRIMARY LOCK

3 - 15 seconds after the stow sequence is completed, the EEC de-energizes the ICV.

Then the EIU opens its internal relays to isolate the ICV and DCV powering.



DCV: Directional Control Valve
ICV: Isolation Control Valve
LGCIU: Landing Gear Control and Interface Unit
RA: Radio Altimeter
TCU: Throttle Control Unit
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GROUND ASSISTED STOW SEQUENCE (GASS)

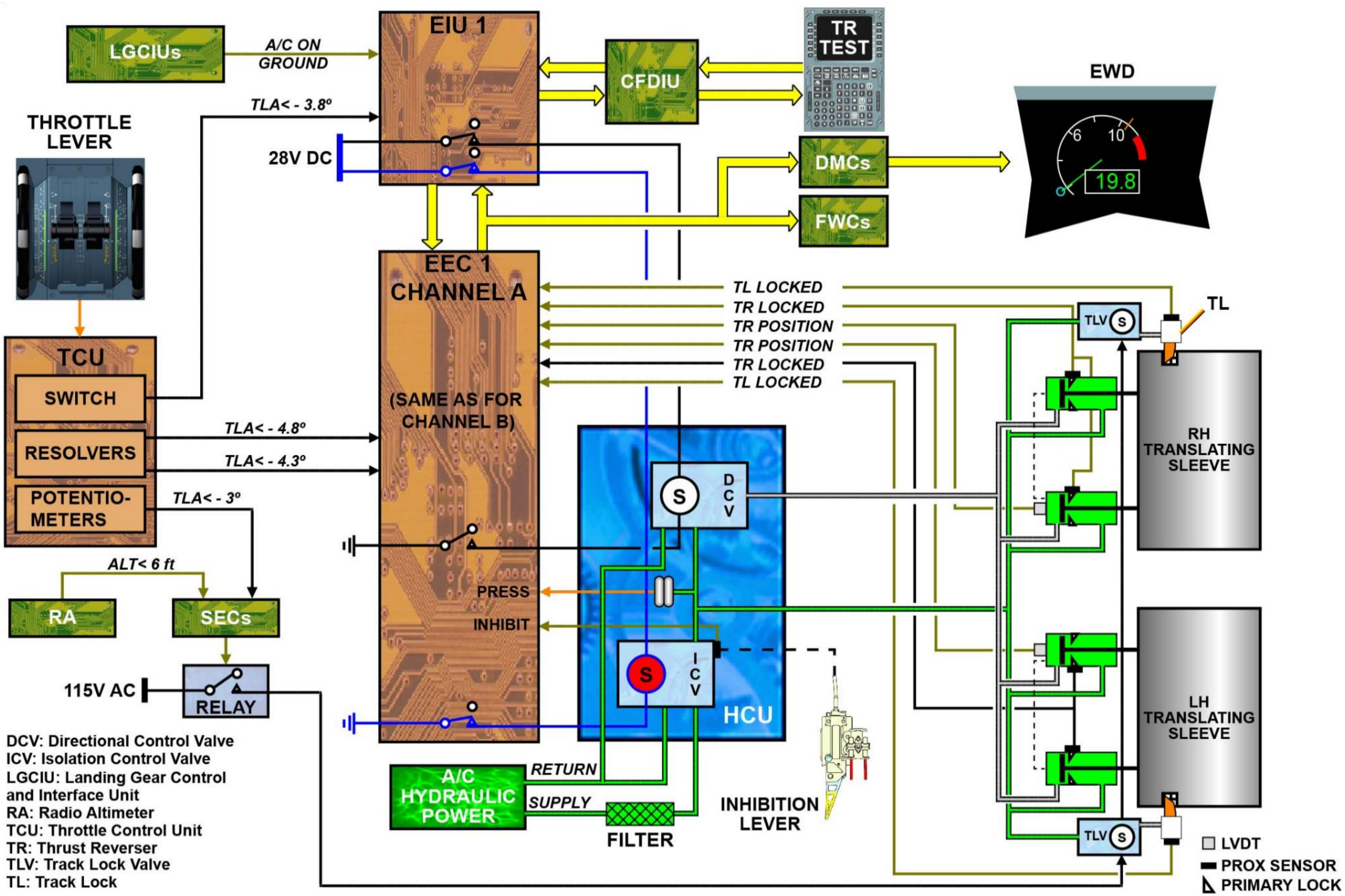
The EEC shall initiate a thrust reverser GASS operation on ground only in order to lock the thrust reverser system in the following two cases:

at least one primary lock is detected unlocked after the normal stow sequence is completed (operational case),

if at least one primary lock is detected unlock after the engine start (maintenance case).

The GASS shall be initiated by energizing the ICV for 5 seconds when all the following conditions are fulfilled:

- the aircraft is on ground,
- the throttle is in forward thrust region and less than CL position,
- no stow sequence is being commanded,
- within 15s after engine transition to idle following an engine start,
- one or two primary locks of any translating sleeve are seen unlocked,
- the sleeve positions (left and right) are less than 5% of travel,
- the thrust reverser is not inhibited,
- 28V DC power is available.


LGCIUs
A/C ON GROUND
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EWD
10
19.8
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